

A
PHYSICAL ESSAY
ON THE
SENSES.

Translated from the FRENCH of

M. L E C A T.

(C.N.)
Illustrated with COPPER-PLATES.



L O N D O N:

Printed for R. GRIFFITHS, at the *Dunciad*, in
St. Paul's Church-yard. M.DCC.L.

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S. E. N. S. E.

Translated from the French of

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Printed for R. GRIFITHS, at the Domesday, in
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TO raise the Curiosity of the Public, for the ensuing excellent and celebrated Work ; it is sufficient to observe, that it is mentioned with Approbation by Dr. PARSONS, in the *Philosophical Transactions*, N^o. 466 ; and by the Authors of the *Monthly Review*, in their first Number, for May, 1749. See also *Bibliothèque Francoise*, Tom. xxxvi. Page 26. and *Bibliothèque Raisonnée*, Tom. xxxi. Page 304.

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PHYSICAL ESSAY

ON THE SENSES.

Of the Touch.

THE Touch participates of less Delicacy than the other Senses; but at the same Time surpasses them in point of Certainty. It absolutely cuts off all Incredulity; besides which good Property, it enjoys that of being the most general Sensation. Seeing and Hearing result from the Organization of a very minute Portion of our Structure; but it is requisite that every Part of the animal Economy should be endued with the Faculty of Feeling, to distinguish us from mere Machines, that may be taken to pieces at pleasure, without the Consciousness of any Violence offered to their Mechanism. This is what Nature has furnished; and wherever we find Nerves and Life, there also subsists this Sort of Sensation; which does not seem to stand

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TOUCH.

 in need of any particular Organization, or to depend on the Structure of the nervous Papillæ, the simple solid Texture of the Nerve being alone sufficient to produce it. The Lips of a green Wound, the Periosteum, or a Tendon, laid bare, have a very quick Sensation, tho' destitute of the nervous Papillæ observable on the Skin. Nature, whom one would conclude necessarily obliged to be at a great Expence in producing this Sense of the Touch, has nevertheless established it at a small one. So that the nervous Papillæ are not absolutely necessary to Feeling, but to the Perfection of it, and the Variety of the respective Sensations. The Sense of Feeling therefore is as the Basis of all other Sensations. 'Tis the Genus, of which they are the most perfect Species. All the nervous Solids, animated by a Fluid, are endued with this general Sensation. But the Papillæ of the Skin, those of the Fingers for example, enjoy it to a Degree of Perfection; which adds to the first Sensation a Sort of Discernment of the Figure of the Body touched. The Papillæ of the Tongue surpass those of the Skin; and, in short, those of the Nose the Papillæ of the Tongue: and so of the rest in Proportion to the Delicacy of the Sensation. What I am advancing, in regard of the Papillæ, does not at all exclude the rest of the nervous Texture from the Share it has in causing Sensation. The Papillæ are more concerned than this Texture, in particular

The Sen-
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cular Organs, as on the Skin, and the Tongue. In others they have a less Portion assigned them; namely, in respect of the Nose, or the Pituitary Membrane, which constitutes the Organ of Smelling. In short, in other Places the Papillæ seem to have still a less Share; and the solid nervous Texture almost singly composes the Organ as in the Sight. These Differences proceed from each Organ's being proportioned to the Object whose Impression it receives. It would be very conducive to the Perfection of the Touch, were the Nerves to form small sensible Eminences: because these Sort of sharp pointed Substances are more easily irritated by the Surface of Bodies, than an uniform Texture could possibly be. The Taste would require nervous Papillæ, that should be of a spongy Nature, and at the same time sufficiently impregnated with Moisture, to dilute and dissolve the Principles of Taste, and to admit them easily into their Texture, in order to their making a more lively Impression. The pituitary Membrane that lines the Organ of the Smell is furnished with soft, downy, Windings, and little Cells, to confine the odoriferous Vapours; but, its Object being subtile, it would have no Occasion either for Papillæ, or sensible Points. The Choroides, the immediate Organ of Sight, has likewise its soft black Down, to absorb the Images that make its Object: but the Bottom of these velvet Substances, formed to receive the

The TOUCH. The Images, ought to be a nervous Membrane, very smooth and very sensible.

Objects of the Touch. All Matter of sufficient Consistence or Solidity to affect the Surface of our Skin, becomes the Object of the Touch. This Sense ascertains the Bulk, and Figure of Bodies, their Distance, Inaction, Motion, Solidity, Softness, Fluidity, Heat, Coldness, Dryness, Moisture, &c. These are its proper Objects.

Heat. The Sensation of Warmth, or Heat, is a Sort of light Emotion, or Irritation of our nervous Parts, and an Expansion of our Solids and Fluids, produced by the slight Action of a moderate Quantity of the subtile Matter that composes Fire, or the Origin of Heat, whether natural or artificial.

When this Matter either exceeds in Quantity, or is more than ordinarily agitated, then, instead of irritating or expanding our Solids and Fluids, it tears them, and dissolves them; and this Violence of Action causes an Inflammation.

Cold. The Sensation of Cold, on the contrary, is a Sort of Obstruction in the nervous Papillæ, and generally in all the Solids, and a Condensation, or Defect of Motion, in our Fluids; arising either from the Contact of some cold Substance, that is to say, of a Substance that is not to any degree impregnated with subtile agitated Matter, like the Air, or Water, in Winter; or by any other accidental Cause, whereby the Motion of our Fluids and natural Elemental Heat is suppressed,

pressed, like the Periodical Convulsion of the Solids that produces the Shivering in an Ague. ^{The Touch.} It is probable, that our Fluids being either totally condensed, or impeded in their Motion, by one or other of these Causes, the nervous Papillæ, and the Solids in general, which are solely expanded by the Impulse of these Fluids, are immediately blocked up; and it is this Constipation, that is the Source of all the Effects of Cold in the Human Body.

The Skin, the Organ of the Touch, is a Composition of Fibres, Nerves, and Vessels, ^{Structure of the Skin.} which are interwoven one with the other in such an extraordinary manner, that the Texture in some measure resembles Network.

This fibrous Texture is visible in thick Shammy, and in the Soles of Shoes made of a thick and soft Leather, where, indeed, the Fibres appear very distinctly.

The Skin adheres to all the Parts it incloses, by means of Blood-Vessels, Lymphatics, Nerves, and sometimes of fleshy Fibres, as in the Face; but commonly by several very thin complicated Foliages, which form themselves into little Cells, where the Extremities of the Arteries seern an Oil, termed Fat. The Anatomists call these Strata of Foliages the *Cellular Membrane*, or *Membrana Adiposa*: Its Structure pretty much resembles that of a Puff-Paste Cake. It is here the Butchers introduce the Air, when they blow

The **Touch.** their Meat, to render it more agreeable to the Eye.

The Skin is formed of all the Parts themselves that fasten it to the Body which it infolds. These Foliages, Vessels, and Capillary Nerves are determined one over the other by the Compression of the Waters that surround the Foetus in the Womb, and, after its Birth, by the Pressure of the Atmosphere. These Fibres, being thus interwoven and pressed together, form the Substance we have been describing. Several of these Vessels, originally hollow, acquire in a short Space a firm Solidity, and become as it were tendinous; and are, with the Nerves, the principal Substance of this thick Texture.

The nervous Capillaries, after having concurred, by their twining and running across one another, to the Formation of the Skin, terminate in its external Surface; where they shed their first Coat, to wit, That supplied by the *Dura Mater*. This first Coat, commonly stiled the Sheath of the Nerve, is divided into several Shreds, that stick entangled together on the Surface of the Skin, and by that means constitute a Sort of Network, called the *Reticular Body*.

The perfect Organ of the Touch.

The Mechanism of this nervous Network is very well accommodated for receiving the Impression of Objects: but the Extremity of the Nerve, stripped of this first Coat, expands and raises itself between the Interstices of this Network,

work, and forms the nervous Papillæ. These are elevated above the Network, are far more susceptible of Irritation, and, consequently, intirely formed for the Production of the most perfect Sensation. A spirituous Lymph moistens these Papillæ, renders them supple and elastic, and of course furnishes an Organ in all respects compleat and accomplished.

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These Papillæ are ranged in Lines, and in a certain Order. And it is this Order that produces the little Ridges observable on the Cuticle, or Scarf-Skin, and so visible at the Ends of our Fingers, where they are spiral.

The nervous Papillæ are perpendicular to the Surface of the Body. At the Ends of the Fingers they are lengthened in Proportion to the Extent of that Part, and are so closely connected together, as to form those solid Bodies, the Nails.

Their very strait Union is the Reason why there is no Passage for the animal Fluid thro' this Composition, whence the Nail becomes insensible. But, to make amends, at the Root of the Nail, where the nervous Papillæ are very solid, very elastic, and remain open to the Flux of Spirits, the Sensation is extreme.

The sanguinary, lymphatic, and oily Capillaries, that penetrate the Texture of the Skin, are distributed almost like the Nerves. Being interwoven one with another in the Skin, they form the vascular Network. Their Expansion

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on the Surface of the Skin constitutes the Excretory Vessels, and the Cuticle that invests the Papillæ, and is very necessary to them, by softening the Impression of Objects; and rendering by that means the Perception more distinct. In short, to this Structure, so adapted to the forming the Organ of the Touch, we must add the Glands situated under the Skin; which serve to supply, at the End of the Lymphatics, the Spirits necessary for the Lymph that moistens the nervous Papillæ, and to bestow on the Animal Fluid a Preparation requisite to the Perfection of this Sensation.

Advantage
of the
Touch.

The Sense of Feeling is absolutely so complete, and of such universal Benefit, that it has sometimes performed, if I may so express myself, the Function of the Eyes, and recompensed, in some measure, the Blind for the Loss of their Sight.

Historical
Relations
on this
Subject.

An Organist in *Holland*, tho' deprived of his Eyes, could notwithstanding play perfectly well. He had acquired likewise a Habit of distinguishing by the Touch the different kinds of Money, and even Colours. Cards could not escape the Delicacy of his Fingers, by which means he became a formidable Gamester: For, in dealing the Cards, he knew the Hands of those he played with, as well as his own.

The Sculptor *Ganibafius* of *Volterre* still surpassed the Organist I am speaking of. It was sufficient for this blind Artist to have touched an Object,

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Object, in order to make a Bust in Clay, that should bear an exact Resemblance. The Touch.

These are the Perfections of the Touch, exceeding all Imagination, and indeed Belief, were they not very well attested. In the mean while, I am apt to think that this latter Instance does not depend so much on a perfect Sensation, as on an extreme lively Imagination. There is no one, but may distinguish the Inequalities of a Face with his Fingers; but, perhaps, it was the peculiar Privilege of the Sculptor *Ganibafus's* Imagination, to be capable of conceiving an exact Likeness, by the Inequalities perceived by the Touch, and of executing it afterwards in Clay.

One Perfection of the Touch, common enough Tickling. indeed, but for this very Reason worthy of our Observation, is *Tickling*, a Sort of Hermaphrodite Sensation; productive of Pleasure, of which it is an Extreme; and of Pain, of which it is as it were the first Degree. Tickling makes us laugh, and at the same time is insupportable. And, if you carry it too far, it becomes a real Evil, and even a mortal one, if any Credit is to be given to Writers on that Subject. This Sensation, therefore, must consist in a slight Stimulating of the Organ of the Touch, like the Irritation that produces all voluptuous Sensations; but what is at the same time still of more Energy, and even quick enough to throw the Soul and Nerves into Emo-

Tickling. tions and Agitations, more violent, than what usually result from Pleasure: and, on that account, this Irritation approaches very near to the Attacks that excite Pain.

The lively Irritation that causes Tickling, proceeds, first, from a Sort of Impression made by the Object, as when the Lips are lightly stroked with a Feather: secondly, from the Disposition of the Organ extremely sensible, namely, the nervous Papillæ of the Skin, being very numerous, very susceptible of Irritation, and furnished with abundance of Spirits. For this Reason, Bodies of a most sensible and most lively Temperament, and the Parts that are best supplied with Nerves, are alone subjected to being tickled. The Organ may moreover be endued with a Sensibility, as it is necessary it should be in order to produce a Tickling, by a Disposition inclining a little to an Inflammation. To this Cause those Itchings must be ascribed, where a light Scratching is the Source of so great a Pleasure. But this Pleasure, like Tickling, borders very much on Pain.

Imagina- Besides these Dispositions of the Object, and
tion pro- of the Organ, Imagination has likewise a great
ductive of Share in this Sensation of Tickling, as well as in
the Sense of all other Sensations.
Tickling.

If any one touches us in the most insensible Places with a professed Intention to tickle us, we cannot bear it. On the contrary, if the Hand be applied to our Skin indifferently, without that seeming

seeming Intention, we are not sensible of any extraordinary Impression; and, in the most ticklish Parts, we can touch ourselves with all the Tranquillity imaginable. Surprize therefore, or Mistrust, is a necessary Requisite to dispose the Organs and the Object for Tickling. This Affection of the Soul determines her to dispatch a greater Quantity of Spirits to these Organs, and to all the Muscles that have any Connexion with them. She there puts them on Action, and by that means renders both the Organ more lively and sensible, and the Muscles susceptible of Contraction on the least Impression. It is a kind of Terror in the Organ of the Touch; which may be compared to that a Hare is under, when she hears the Cry of the Dogs.

This odd Phenomenon, in regard of Tickling, is a Confirmation of the Alliance there is between the Soul, and the Organs of Sensation. But, I am apt to imagine, that there is no Fact more singular, in respect of this reciprocal Correspondence, than the Story recounted by St. Augustine. He tells us, that a certain Parish-Priest, named *Resitutus*, was possessed of a Soul so absolutely Mistress of the Senses, that he could at pleasure intirely deprive them of their Faculty of Feeling, and become like one dead. Tho' burnt, or pricked, he still continued insensible. Nor was he apprized of having been pricked or burnt, but by the Marks that remained on the Skin. He could likewise

A Priest who could deprive himself of all his Senses.

intirely

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Touch.

intirely suspend all manner of Sign of Respiration.

I have either read it somewhere, or have heard somebody strenuously assert it, that a certain Person, endued with a Faculty not unlike this, one Day in agreeable Company, having succeeded extremely well in dying thus voluntarily, over-acted his Part so far, as to forget to raise himself to Life again.

Sensation
of Love.

The Tickling, we have been just explaining, leads us naturally to another Kind of Sensation arising from the Touch, that is more perfect, more general, and essential to all Animals for the Propagation of their Species. This Sensation is a Sort of Taste for Immortality. The Sense properly called Taste, prompts us to take necessary Nourishment for the Preservation of Life; but this other Kind of Taste inflames us with a Desire of giving Being to others, and so to perpetuate our Race to the End of Ages.

Tho' this Sensation be only an extreme Delicacy of the Touch, which it possesses in common with all the Senses; it is nevertheless very distinct from simple Touching, and, indeed, much more so, than the Smell differs from the Taste. One may even confidently assert, that it has an undoubted Superiority over all the Senses, both by reason of its End, and of its Object, and the Nobleness of the Sensation itself. It is to this End all Beings endued with Life

Life owe their Existence. The Objects of all the other Senses are material, foreign, Bodies; the Object of this Sensation is no less than another Sensation. It is an Organ full of Life and Spirits, that communicates them to another: Or rather, it is almost a general Commerce of all the Senses, and principally of all the Kinds of the Sense of Feeling. In respect of Sensation itself, if Love be put in Competition with the Appetite, we shall scarce perceive any Room for Comparison. The latter, to a small Pleasure, joins a Mixture of Baseness, conformable to Sensations worthy only of mere Brutes. To the former is attached a Sensation, that entitles it to the Name of Pleasure, and that in an eminent Degree, connected with Affections that hold all Nature in the softest Chains; and the Sublimity and Delicacy of which is the most remarkable Characteristic of Human Nature, and the most valuable Property of the Heart and Soul.

A Sensation, that is capable of being raised even to a Degree of Moral Purity, and sublime Metaphysics, might very well deserve to be expressly treated of in a Work of this Nature, which has on other Accounts a Prerogative to discuss Subjects of such Sort; and, perhaps, this might not be the least curious Province for real Naturalists. But there are so few of these, in respect of the prejudiced Part of Mankind, that, out of a Regard to the Infirmities of a
great

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Touch.

great Number of People, we will leave it to intelligent Persons to apply to this Sense Part of what we shall advance concerning the Taste, and other Senfes, that have the most considerable Connexion with it.

Of the TASTE.

THE TASTE, considered superficially, would seem to be a Sensation peculiar to the Mouth, and distinct from that of Hunger and Thirst. But, if we trace it to its Origin, we shall be convinced, that this Organ, which in the Mouth makes us sensible of the Delicacy of Meats and Drinks, is the self-same Principle, that in the Mouth, Gullet, and Stomach, is craving for Food, and incites us to a Longing after it. These three Parts, properly speaking, are but one continued Organ, and have but one and the same Object. If the Mouth creates in us an Aversion to any particular Food, does not the Gullet recoil at the Approach of it? And does not the Stomach immediately discharge its disagreeable Contents? Hunger, Thirst, and Taste are therefore three Effects of the same Organ. Hunger and Thirst are the Motions of the Organ desirous of its Object. The Taste is the Motion of the Organ in the Enjoyment of this Object: it being a Point past all Contest, that the Soul, united to the Organ, is the only real Subject of Sensation. This Unity of the Organ, in regard of Hunger, Thirst, and Taste, is the Cause of these three Effects being almost ever in the same Proportion

The Proportion in the same Persons. The more violent
TASTE the Appetite for Food is, the greater is the Enjoy-
ment in Eating. The more the Taste is gratified,
the more easily the Organs defray the Expence of
this Gratification by Digestion. Because all these
different Degrees, which I suppose the Result of
a sound Habit, proceed from an Organ, that is
more healthy, more perfect, and more robust.
This Rule is general in regard of all the Sensa-
tions, and all the Passions. Genuine Desire con-
stitutes the Proportion of the Pleasure, and of
the Power; because the Power that gives Rise
to the Pleasure, is also the Measure of it, just as
the Pleasure is limited by the Desire of it. The more
voracious the Stomach is, the greater Pleasure arises
from Eating, and proportionably stronger is the
Appetite. Without this mutual Consent, founded
on the Mechanism of the Organ, our Sensations
would destroy that Being, for whose Benefit they
are established. A Gormandizer with a weak
Stomach would die with Indigestion; while
another Person with a voracious Stomach, but
without Taste or Appetite, would, if it were
possible, perish both by the Torment of his
Voracity, and for want of proper Sustenance;
which this Want of Appetite and Taste would
deny him the Power of receiving, or digesting.
In the mean while, how often is the digestive
Power overcharged by the Appetite, especially
in Men? because they do not follow the simple
Motions of their Organs and Powers, as much

as

as Brute Animals do: but, by indulging a lively Imagination, which is still more fired by Artifices, confound the Harmony and Order, established in Nature by it's Author. Let them therefore no longer condemn the Senses, and Passions, to which they owe nothing but Gratitude; but ascribe their Irregularities to an unbri-dled Imagination, and an Impotence of Reason, that has not Force sufficient to restrain it.

The Taste, in general, is the Motion of an Organ, that enjoys its Object, and is intirely sensible of its Goodness. It is for this Reason, that there subsists a Taste in regard of all Sensation; Taste for Musick and Painting, as well as for what we eat or drink; as the Organ of these Sensations, if we may use the Expression, has a Relish of these Objects.

Tho' the Taste, strictly taken, is common to the Mouth, Gullet, and Stomach, and there is such a Sympathy between these three Organs, that what is disagreeable to one, is generally repugnant to all; and tho' they are in a Sort of Combination to get rid of what is disgusting; yet it must be confessed, that the Mouth possesses this Sensation in a more eminent Degree, and is endued with a greater Delicacy than the other two. A Bitter, that causes such an Antipathy in the Mouth, as to create a Nausea, will, in the Stomach, only prove a moderate Stimulus, just sufficient to awaken its Faculties. It is very natural that the Mouth, which first

The TASTE. receives the Aliments, and of course becomes the Taster, as it were, in respect of the other two, should be endued with a discerning Property beyond them. It is the Part of a good Clerk of the Kitchen to distinguish himself by an elegant Choice of Provisions, to prevent his incurring the Displeasure of his Superiors.

This delicate Sense is evidently the most essential of all the Senses, after that of Feeling; and, indeed, more essential than the Touch, were not the Taste itself a Sort of a more refined and subtil Touch. So that the Object of the Taste is not a solid Body, as is that of the Touch; but they are Juices, or Moisture, with which these Bodies are impregnated, or that are extracted from them.

The Mechanism of Savours.

These Juices, or Moistures, that make an Impression on the Organ of Taste, are called *Savours*. And sometimes this Appellation is appropriated to their Impression itself. The active Principles of Savours, or of savoury Bodies, are Salts, as well fixed as volatile. Earths, Phlegm, and Sulphurs are no Part of savoury Compositions, but serve to establish a Variety; in the same manner as Shades, mixed with Light, form different Images. But at the same time these Shades make no Impression on the Organ, that being intirely the Effect of Light. Thus Salts are the only Principle capable of affecting the Organ of Taste. It is a Maxim universally known, that Water, Oil, and Earth have not the

the least Taste. Lymph then, or Water, is only the Vehicle of the Salts, dissolving and conveying them; and their Mixture with Oil and Earth only makes them vary their Impressions a thousand Ways. If to these Varieties be added those, which result from the Nature of both simple and compounded Salts, the Variety of Savours will become an inexhaustible Source. What a Variety of Images does Light produce with Shade alone! Again, what farther Variety arises from the blending of a few original Colours, and from Shade! Ought we to be less attentive to the Mixture of primitive Salts with one another, and with Water, Earth, and Sulphur?

The
TASTE.

Such is the Nature of Savours in general: now let us examine the Organ on which they act. Organ of Taste.

The nervous Papillæ are here too the Organ of Sensation. All that is new in it is, that their Structure is a small matter different from that of the Papillæ of the Skin, and that in Proportion to the Disparity of their Objects. The Papillæ of the Skin, which are the Organs of the Touch, are small, and of a compact fine Substance. They are covered with a Membrane sufficiently smooth, and of a close Texture. The Papillæ, that form the Organ of the Taste, are much larger, more porous, and more open. They are moistened by a great deal of Lymph, and invested with a Skin, or inclosed in Sheaths, very unequal, and at the same time very porous.

In Consequence of this Structure, the savoury Particles are detained amidst these Asperities; diluted and dissolved by a great Plenty of this Lymph, absorbed by these Pores, and conveyed by the Assistance of this Lymph to the nervous Papillæ, where they make an Impression by their stimulating Faculty.

These Papillæ, the Organs of Taste, are not only very numerous on the Tongue, but are besides scattered here and there in the Mouth. We discover them, by Dissection, to be dispersed on the Palate, the inner Jaw, at the Root of the Mouth; and by Observation we are confirmed in our Opinion concerning their Use. Monsieur *de Jussieu*, in the Memoirs of the Academy, relates the Story of a Girl born without a Tongue, who was not for all that deprived of Taste. A Surgeon of *Saumur* saw a Boy of between eight and nine Years of Age, who in the Small-pox had intirely lost his Tongue by a Gangrene, so that there remained not the least Traces of one; and yet, notwithstanding, he had a very distinct Taste of whatever he put into his Mouth.

However, it must be confessed, that the Tongue is the principal Organ of this Sensation. Its Substance consists of fleshy Fibres, by means of which it assumes different Forms. These Fibres are surrounded by, and interspersed with an oily Substance, that renders the Composition more supple. Part of these fleshy Fibres
extend

extend themselves beyond the Tongue, and are fastened round about it, and form the exterior Muscles that determine its Motion every way. This fibrous Body is inclosed in a Sort of Sheath, or very strong Membrane.

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TASTE.

A Nerve of the ninth Pair, after its Ramification among the Fibres of the Tongue, is terminated on its Surface. The Ramifications of this Nerve, stripped of their first Coat, form the Papillæ we have been discoursing of. These Strippings strengthen the Covering of the Tongue, and contribute also to Sensation. The Papillæ, divested of their Coats, appear by their Figure of three distinct Classes; one of which resembles a standing Mushroom, another Lenticils, and the third shews itself in the Shape of Pyramids. The two first have a visible Perforation in several Places, from whence oozes a limpid, watry Matter. All this Apparatus is shrouded by a very porous Cuticle, that distributes Sheaths to the nervous Papillæ.

The various Motions the Substance of the Tongue is susceptible of, promote the Secretion of the Lymph which moistens the Papillæ, open the Pores that convey it to them, and determine the savoury Juices to enter them.

When the Salts, that are introduced into the Pores of the Organ of Taste, are whole and intire, and no ways softened by any Mixture, they are violently pungent, and in Consequence of that Pungency, obtain the Name of *Disagreeable*; inasmuch

Difference
of Savours.

asmuch as this Violence shocks the sensitive Substance. Of this kind are generally acrid, acid, salt Bodies, &c. when they are not mixed with any other.

When the Salts are sheathed by the oily or sulphurous Parts, so that their Edge is intirely blunted, and their Points even entangled in that manner that they can but very lightly irritate the nervous Papillæ, then this light Irritation produces a sweet *agreeable* Taste; as it excites in the sensitive Fluid that voluptuous Emotion, in which consists the very Essence of Pleasure. Such, ordinarily, is the Effect of Sugar, composed of salt and sulphurous Ingredients.

These are the two opposite Savours. Between these two Extremes, and even in each of these Extremes, arise innumerable Varieties.

I have just been asserting, that violent, acrid Savours are generally disagreeable; and that the Savours which do but, if I may be allowed the Expression, just tickle the Organ, are for the most Part agreeable: I must further add, that the Pleasure, or Disagreeableness, resulting from Savours requires them to exert a certain Degree of Violence or Tickling; and that a particular Disposition in the Imagination, on which the Impressions are made, must likewise necessarily concur to produce those Sensations.

All sweet or light Savours are not agreeable, nor all acrid disagreeable. Some Sweets are insipid: and there are acrid Substances which

are

The
TASTE.

are actually a Gratification to some peculiar Palates. And every now and then we meet with one, in whom the finest of Sugar shall cause Reachings. Imagination therefore bears a Part in the Sense of Taste, as well as in all other Sensations. As to my own Particular, how comes it to pass, that I had formerly such an Aversion to the Bitterness of Coffee, which now affords me no small Regale? How came the first Oyster that I swallowed, to create in me as much Nausea as a Medicine, and by degrees to become one of my most delicious Repasts? In the mean while, neither the Action of the Coffee, nor that of Oysters upon my Organs is inverted; and the mechanical Disposition of these Organs is also pretty much the same. All the Alteration therefore arises from the Part the Soul acts in the Affair, which does not form to itself the same Ideas on Occasion of the same Impressions. There is then no Idea essentially annexed to such, or such Impressions: at least there is no one which it is not in the Power of the Soul to alter. Hence some peculiar Dishes are fashionable in particular Countries; and what is the Delight of one Nation is often the Dislike of another. Hence it is, in short, that thro' Custom we sometimes transform that which at first is disagreeable, into an Object of Pleasure.

Of the SMELL.

WE have in a former Treatise, placed Man in a State of Consciousness of his Existence: we have furnished him with the first Means of preserving his Being, by nourishing it: we have placed him at Table with a Taste and Appetite: but what Assurance can he have, that this Table that is served up to him, is spread with Aliments suitable to his particular Condition? He does not as yet enjoy the least Glimmerings of Light: and, if he did, his Eyes could not at all ascertain the Goodness of his Food, nor even perhaps demonstrate it was really Food, it being not their Province. Let us then procure him the Enjoyment of succulent and delicious Odours, that exhale from the Meats and Drinks that are prepared to regale him. Let us endue him with *Smell*. These odoriferous Particles have no sooner touched this Organ, than the Irritation immediately expands itself all over the Organ of Taste; and this being put upon the Scent, furnishes in an Instant every Machine requisite for seizing the Prey.

I imagine therefore, that the Smell is not so much a particular Sense, as a Part of, and Supplement to, that of the Taste, to which in a manner it stands Centinel. In a word, the Smell

The
SMELL

is the Taste of Odours, and as it were the Anticipation of savoury Bodies. The Membrane, which lines the Nose, and is the Organ of this Sensation, is a Continuation of that which lines the Throat, the Mouth, Gullet and Stomach; and the Difference, in regard of the Sensations of these Parts, is pretty high in Proportion to their Distance from the Brain. That is to say, the Smell differs no more from the Taste, than the Taste does from Hunger and Thirst. The Mouth is endued with a finer Sensation than either the Gullet or Stomach; and the Nose enjoys one still more delicate than the Mouth, by reason it is nearer to the Source of Sensation. And, again, all the Filaments of its Nerves, and of their Papillæ, are fine, hollow, and full of Spirits. Whereas those that are distant from this Origin, acquire, thro' the natural Tendency of the Nerves, a greater Solidity, and become thicker coated, their Papillæ degenerating into a kind of Excrecence: Now all the World knows, that Excrecences are not endued with any great Degree of feeling.

Nobody is ignorant that the Inside of the Nose is the Organ of the Smell; but very few have a just Notion of the Mechanism with which this Inside is contrived in order to receive this Sensation*.

Immediately after the Opening of the Nostrils, which is sufficiently strait, the Inside of the Organ of the Smelling.

* Consult the Figure annexed.

^{The} ^{SMELL} the Nose forms two Cavities, which are ever separated by one Partition. These Cavities are enlarged in Proportion to their Distance from their first Entrance; and they are again united in one intire Cavity, that extends itself even to the Bottom of the Throat, by which means they have a Communication with the Mouth.

All this Cavity is lined by the Pituitary Membrane, so stiled by the Ancients, by reason of the Phlegm that is continually flowing thro' it. This Membrane is of a spongy Nature, and has on its Surface an exceeding soft and short Down. The spongy Texture is formed by Vessels and Nerves, that are interwoven with a great Number of Glands. The Down is composed of the Extremities of these Vessels, to wit, of the small nervous Papillæ that constitute the Organ of Smelling, and of the Extremities of the Vessels thro' which flows the Phlegm, and the Mucus of the Nose. These Liquids lubricate the nervous Papillæ, and render them fit for discharging their Function; and are farther assisted in this Office by the Tears, which the lachrymal Canal conveys along the Nose.

The olfactory Nerve, the first Pair of Nerves that proceed from the Scull, is that which spreads itself in the Pituitary Membrane. Its Filaments are in great Number, seem to be softer, and are more visible than in any other Organ.

This

This Structure of the Nerves, subservient to the Smell, whose Efficacy depends on the near Connexion they have with the Brain, renders them still more susceptible of receiving the Impression made by odoriferous Bodies.

The
SMELL.

The great Number of Filaments that constitute the Olfactory Nerve, is what produces the numerous Glands in the pituitary Membrane; these Glands being nothing else than the Extremities of the Nerves expanded about the Papillæ.

Besides the Olfactory Nerve, there enters the Nose a Branch of the Ophthalmic, that is to say, of one of the Nerves of the Eye. It is the Communication of this small Nerve with that of the Smell, which is the Cause that we shed Tears on Occasion of any strong Scents, and sneeze at the Rays of the Sun being directly darted on our Eyes: because this small Nerve, in its Origin, is connected with the Nerves distributed in the Organs of Respiration. So that on any quick Irritation, it excites in these Organs those convulsive Motions, from whence results Sneezing.

Strong O-
dours
make us
weep, and
strong
Rays of
Light
sneeze.

The downy Coat of the Pituitary Membrane is intirely proper for imbibing the odoriferous Fumes: but there is still another Contrivance for fixing these Particles on their proper Organ. The Inside of the Nose is furnished on each hand with two Sorts of complicated Windings, which advance very far in this Cavity, cause a

The
SMELL

Sort of Obstruction in the Passage of it, and oblige by that means the odoriferous Vapours to diffuse themselves, and to stop a limited while within their Capacity.

This Structure determines these Vapours to act a longer Time, in a stronger Manner, and on a larger Extent of the Pituitary Membrane; and, consequently, the Sensation resulting from thence is rendered the more perfect. For this Reason, Dogs of the Hunting Kind, and other Animals that are remarkably distinguished for the Perfection of their Smell, have these winding Cavities in their Noses considerably larger than Mankind have.

These same Windings, in stopping a little the Air respired thro' the Nose, soften the Rigour of it in Winter. And it is this good Office which they render the Lungs, that exposes the Pituitary Membrane to the greatest Share of those Obstructions called Rheums, and Defluxions of the Head. In these Disorders, the mere Swelling of this Membrane shuts up the Passage of the Air; because the Coats of the Fibres being grown thicker, immediately close. Which is a Demonstration, that altho' the Cavity of the Nose be very considerable, the Labyrinth, notwithstanding, that Nature has established in its Mechanism, in order to the tasting, if the Expression be allowable, of Odours, leaves but a very small Portion of empty Space.

The

The odoriferous Fumes, which constitute the Object of the Smell, are in respect of a Fluid, what savoury Bodies are in regard of Liquids and Juices. A Salt is ever the Agent, or at least the Instrument and Stimulus of the Sensation. All Salts without distinction produce Tastes; but they must be volatile, to affect the Organ of the Smell. Aqueous, sulphurous, &c. Vapours, dissolve, convey, modify the Impression of Salts, and concur to diversify the Scents. In a Word, all that I have delivered on the Subject of Tastes, is exactly applicable to the volatile Fluidity of odoriferous Bodies.

The
SMELL.
Mecha-
nism of
Odours.

The prodigious Quantity of these volatile Fluids, exhaling incessantly from an odoriferous Substance, and that without any sensible Diminution of its Weight, is a Proof, that Matter may be divided in an astonishing manner.

The general Vehicle of these scented Corpuscles is the Air. These little Bodies are diffused in the Atmosphere, and are there sustained: either because they form a subtil Fluid, as light as, or lighter than, Air; in which of course they must remain in an Equilibrium, or rise according to the Laws of Hydrostatics; or these Corpuscles, tho' heavier than Air, yet fly upwards in this Fluid, by reason of the great Velocity with which they are ejected from the odoriferous Body, and by the Velocity of the Air itself, which concurs to bear them aloft. As a Horse on full Speed, and the Wind together,

Vehicle of
Odours.

The
SMELL.

gether, raise a Cloud of Dust much heavier than the Air in which it floats.

It is not sufficient that the Air be in a manner impregnated with odoriferous Particles; it is likewise necessary that they be conveyed to the Cavities of the Nose, which is the natural Consequence of Respiration. This obliges the Air to pass and repass incessantly thro' these Cavities, in order to its Entrance into the Lungs, or its Departure from thence. For this Reason, those that have the Passage of their Nose obstructed by a Catarrh, and so are under a Necessity of respiring by the Mouth, are deprived at the same time of the Faculty of Smelling. Monsieur *De la Hire* the younger once saw a Person who prevented his being sensible of any disagreeable Scents, by raising up his Uvula, so as to cut off all Communication of the Nose with the Mouth; whence he respired for the future this latter Way *.

This same Passage of the Air thro' the Cavities of the Nose, serves sometimes to cleanse them from Obstructions; as when it is forced violently from the Lungs, either in blowing the Nose, or by sneezing.

Effects of
Odours. There is not only a Gratification, or else a Disagreeableness in Odours, as there is in Tastes; but they likewise support the languid Powers, by stimulating the Nerves, and recruiting them with a fresh Supply of Spirits. They sometimes

* Observ. Physiq. Tom. II. Pag. 103.

sometimes also disconcert the same Nerves, put them into Convulsions, and produce Vapours and Swoonings, when they make a displeasing Impression. The Imagination, as to this Point, is not stripped one Jot of the Rights we have established in it, over all the Senses. Whence is it, that Musk, so favourite a Perfume formerly, should at this time o' Day be a general Source of vapourish Disorders in the fair Sex, and even some few of the Men: whereas Tobacco, of an ammoniacal and venomous Flavour, conveys one of the most delicate, the most delightful Smells in Nature? Is it because there is an Alteration in the Organs? No! It is Habit, Prejudice, Imagination.

The
SMELL.

Imagination bears
a Part.

Mankind, ordinarily speaking, have not the Sense of Smelling to that Perfection which Brute Creatures have, the Reason for which Difference we have accounted for. The Rule notwithstanding is not absolutely general. There are Negroes in the *Antilles* Islands, who like Dogs follow their Masters by the Print of their Feet, and distinguish by their Nose the Track of a Negroe from that of a *Frenchman* *.

Singular
Perfection
of the
Smell. Its
Causes.

If any Credit may be given to Sir *Kenelm Digby*, a Boy, whom his Parents had brought up in a Forest, (whither they had fled to avoid the Calamities of War) and who had lived on nothing but Roots, had a Smell so delicate, that

Strange
Relation
of Sir
Kenelm Digby.

* Observ. Physiq. Tom. II. Pag. 103.

The that by this Sense he perceived the Approach of
SMELL. the Enemy, and apprized his Parents of their coming. He was in the mean while made Prisoner; and, having altered his Method of living, in length of Time he lost much of that surprizing Delicacy of Smell. However, he was not intirely deprived of this singular Faculty. For being married, he could very easily by smelling distinguish his own Wife from another Woman, and even find her out by the Print of her Foot, as a Dog does his Master. A Husband of this kind would in *Italy* make an *Argus* still more terrible than the famous one in the Fable.

It seems then, that the Perfection of the Smell, in Brute Animals, not only depends on the Organ, but likewise on the manner of living, and on the Privation of those strong Odours, with which Mankind are constantly surrounded, and to which their Organs are so much accustomed, that Scents so weak and so subtil, as those we have been speaking of, cannot make the least Impression on them.

Monk of The Monk of *Prague*, mentioned in the
Prague. *Journal of the Learned* of the Year 1684, is still a more extraordinary Case, than the preceding. He not only knew different Persons by the Smell; but, what is much more singular, could, we are told, distinguish a chaste Woman, married or unmarried, from one that was not so.

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SMELL.

fo. This Religious had begun to write a new Treatise on Odours, when he died, very much lamented by the Gentlemen who record this Story of him. For my Part, I do not know whether a Man of such Talents would not have been dangerous to Society.



the Touch of the Solidity of Bodies
and their principal Properties in re-
gard of us. Then we discovered the very Mo-
tion of the Joints and Ligaments with which
of these Bodies are impregnated, and even the
Tumes that exude from their Substances.
In short, we have been made sensible both of the
grosser and the more subtle Parts of most Bo-
dies, that are within our Reach and Contact.
This limited Commerce might volitionally be in-
creased for us; and, in effect, is sufficient for
us, that are still to be instructed by Nature.
Of course her Liberal has been more benedi-
ctive to us, and extended our Communication with
other Beings far beyond those that surround
by the Hearing, and even far beyond the World
we live in, by the Sight.
This Communication is ever established by
the Matter that is its Origin; but in Pro-
portion as this Matter advances, it becomes
more and more subtle, it more and more cap-
tured at a Distance, and more and more cap-
able of bringing us Tidings from a far, that we
altogether foreign to our Ambition.

Of the HEARING.

OUR Perfections increase insensibly. In the first Place we were assured by the Touch of the Solidity of Bodies, and their principal Properties in regard of us. Then we discovered the very Motion of the Juices and Liquids; with which some of these Bodies are impregnated, and even the Fumes that exhale from their Substances. In short, we have been made sensible both of the grosser and the more subtile Parts of most Bodies, that are within our Reach and Contact. This limited Commerce might absolutely be sufficient for us; and, in effect, is sufficient for a few, that are said to be ill-treated by Nature; because her Liberality has been more beneficent to us, and extended our Communication with other Beings far beyond those that surround us, by the *Hearing*, and even far beyond the World we live in, by the *Sight*.

This Communication is ever established by the Matter that affects an Organ: but, in Proportion as this Matter advances, it becomes more and more subtile, is more and more expanded at a Distance, and more and more capable of bringing us Tidings from a-far, that are altogether foreign to our Atmosphere.

We

We are now on the Point of transcending the Bounds of this Atmosphere. For the Object of ^{The} Hearing is Noise in general. Now Noise consists in a quick Vibration of the Air, communicated to the very Organ of this Sensation; and this Communication, it is very well known, is set on Foot at a great Distance.

The Noise, which renders the Vibrations of the Air fuller, more regular, and, consequently, more pleasing to the Ear, is called *Sound*.

The Vibrations of Sound, in producing an agreeable Surprize, have excited Men's Curiosity and Industry, to form them into an Art adapted to please and move them, by the Sense of Hearing. All the Senses have been equally productive of Arts to gratify, or perfect, or to guard themselves from bad Impressions. What Arts has not the Sense of Feeling produced? These Garbs, magnificent Houses, gilded Chariots, are all the Effect of Delicacy. If the Ear has its *Lullies*, the Mouth is not without its *Martials*, nor the Eye its *Galileos*, &c. All of them valuable in their Way, because they have applied themselves to the Improvement of Human Nature. Let us now examine, as Philosophers, some of the Principles of simple Sound, and of Sound reduced to an Art.

The
Hearing.

The MECHANISM of SOUNDS.

SOUND is, in the sonorous Body that produces it, the same it is in the Air itself that conveys it to the Ear; viz. the shaking of a Body, put into Motion by the Impulse of some other. Such is a Bell struck by its Clapper; a Violin shook by its Strings, which the Bow sets a trembling; a Flute agitated by the Impulse of the Air against its Embouchûre.

The Air
that pro-
duces
Sound is
not com-
mon Air.

It is a Mistake to imagine that the Air, put into Motion by sonorous Bodies, is this gross and palpable Air, which we fan with our Hat, and blow the Fire with. The Sound of the largest Bell does not communicate the least Motion to the Flame of a Candle: whereas the least Breath of Wind, that is to say, the smallest Motion of gross Air, gives it a Tremor, and extinguishes it.

The Air therefore, that produces Sound, as it is proportioned to the Organ of Hearing, is much more subtile than common Air.

Motion of
sonorous
Bodies for
Sounds.

The Motion of a sonorous Body is compounded of two others, namely, of the trembling of all the small Parts that compose this Body, and the vibrating Motion resulting from the whole.

In Consequence of the first Motion, or Trembling, the Particles of the Body approach to, and retire alternatively from, one another with

a prodigious Velocity; whence their respective Situation and the Figure of their Pores change without ceasing. The Hearing.

In the Vibration of the whole Body, there falls out amongst the Surfaces of the Body, what we have been just observing to happen amongst the Particles concerned in the Trembling: For Instance, a Bell, when it sounds, from being round, becomes oval; and so, *vice versa*, Millions of Times in a Moment. A String likewise, tho' strait, and extended upon the Bridge, from it's natural Straitness is curved here and there an Infinity of Times, in a very little Space.

Both the one and the other Motion produce Sound; and the Duration of the Vibrations, as well of the intire Body, as of its Parts, determines the Species of Sound, flat, or sharp. For Example, a long String, or a small slack one, or one formed of Matter very little elastic, gives a flat Tone; because the Vibrations of a String of that Kind are slow, grand, and at a Distance from one another. On the contrary, a String wound up high, or made of Matter endowed with great Elasticity, produces a sharp Sound, by reason its Vibrations are short, quick, and close. Supposing therefore two Strings of the same Matter, of the same Size, and equally extended, and one of which is the Moiety of the other, that which is but the Moiety, will found the Octave of the other; because its Vibrations are as short again, and equivalent to

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Hearing.

those of the other. These Octaves are attended with an harmonious Effect, as, from the double Vibrations, made by the small String, one of them is ever falling in with the Vibrations of the larger; whereby they concur to render the sonorous Vibrations more compleat, put a greater Quantity of Air in Motion, and are consequently more agreeable. This is the Principle of all musical Harmony, and particularly the Mechanism of playing on the Violin, and of all Instruments whose Tones are produced by the shortening of the Strings, in Consequence of the Disposition of the Fingers. The more Vibrations there are that concur, the more perfect is the Harmony. On which account the Unison is the first and compleatest of all this Class of Sounds, or rather, is of itself true and perfect Musick: because, in this State of the Strings, all their Vibrations are in Concord, and always strike the Air together. Discordant Tones are those, where there are no concurring Vibrations.

In Consequence of this Equality and Regularity of Vibrations in the Unison, when the String of an Instrument is touched over against another that has a String wound up in the same manner, this latter String is agitated by the Sound of the former; because this String, being in the same State, and disposed for the Unison, falls in with the Vibrations of the Air, whose Returns are conformable to the Length and Tightness of it, and, in short, to the Vibrations that result from

it: whereas the Motion of the other Strings, whose Vibrations are discordant, is soon interrupted, and suppressed by those very Vibrations of the Air, that are instantly making their Efforts to excite Vibrations in it. To have a clear Conception of this Consonance, and of its Defect, suspend a Ball on a Thread, and poize this Ball in the Air, giving it a Push with your Finger. If you have a Mind to carry on the Vibrations of this Ball, you must accommodate yourself to it, and be careful to push it at the End of every Vibration, when it is on the Point of beginning another. Thus may you continue these Vibrations as long as you please, and be in the Case of the String in the State of Unison with another. But should you, in Contradiction to the Vibrations of your Ball, go abruptly to touch it in the Middle of its Career, you will stop the Ball. And this is what the Air does, that is shook by a String, in regard of the other Strings with which it bears no manner of Consonance, in Opposition to all Unison.

This is the Principle of the Difference of Tones, and harmonious Accords. As to the Force of Sound, this depends on the Quantity of Air, put in Motion by the sonorous Body; and this Quantity depends either on the Force of the Vibrations of the sonorous Body, or on its Extent. A Person in the same Key, and of the same Bulk of Voice, will sooth the Ear by moderating the Impulse of the Air in his Or-

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Hearing.

gan, and be able at the same Time to stun one by exciting more violent Vibrations. But should he multiply these Vibrations by a vastly high raised Voice, or by an Instrument that puts a great deal of Air in Motion at once, his Voice will then produce a Noise, that will almost be insupportable, and carried to a great Distance. These Principles are very applicable to the Trumpet, French-Horn, and to other loud-sounding Instruments; because they agitate a large Quantity of Air, and agitate it violently, by reason of the great Elasticity of the Matter of which they are composed.

This I have been discoursing of has been long known to the World: But our Moderns have enriched the Subject with fresh Discoveries, and intirely new Hypotheses.

On touching two Strings of a Violin at once, that are tuned to a Fifth, one may perfectly hear the Sound of both. In the mean Time, one of these Sounds consists in a double Vibration of the Air, and the other in a triple. But the same Mass of Air cannot produce at one and the same Time three Vibrations of one Part, and two of the other, and those distinct from one another. If you throw two Stones at once into a Lake, hard by each other, the Undulations they will form in the Water, will either be confounded in one alone, or be mutually destroyed. For the same Liquid is not susceptible of two or more different Vibrations at once!

The

The contrary is, however, the Case, in the Fluid that produces Sound, which receives at once the Impression, not only of two, but of all the different Tones of Musick, and conveys them distinctly to the Ear. It is necessary then that the Air, which generates Sound, be composed of several Species of Fluid, more or less subtile, each of them endued with a Property of producing the Vibrations, or the different Tones of *Ut, Re, Mi, &c.* much after the Manner as Light is formed of several Kinds of Rays adapted to the Production of Red, Yellow, Green, Blue, &c.

The
Hearing.

Species of
Air pro-
ductive of
Tones,
compared
to original
Colours.

Supposing this to be Fact, one may easily conceive, that each Tone will affect its own peculiar Fluid, or that whose particular Vibrations constitute this Tone; by which means the Ear is capable of receiving at once all the Impressions of each of these Fluids, and of every one of these Tones, as the Eye receives at once the Impulse of several Colours.

On touching only one String of an Instrument, the Generality of Mankind are sensible but of a single Tone: whereas those that are versed in, and accustomed to, Musick, distinguish, besides this fundamental Tone, the Octave, the Fifth, and the Tierce, absorbed in the principal Tone. From hence chiefly results all Harmony.

Now by the Principle of shortening the String, which we have been speaking of, the
Octave

The
Hearing.

Octave is the Moiety of the Fundamental Sound, or the Product of half of the String; the Fifth is the Product of two thirds of the same String; and the Tierce the Product of four fifths of it.

It is Matter of Fact, say the Journalists of *Trevoux*, that the Parts of an extended String, are extended unequally from each End to the Middle. The Trembling alone of the String makes a natural Division of it: for which Reason one may imagine, that the middle Part of it, being less extended, produces the total Sound; and that the other Portions will make a Tierce, a Fifth, and an Octave, as they approach the Ends of the String, according to the Order I have been recounting.

It would be better, in my Opinion, to apply here the Species of aerial Fluids proper to each Tone; and, by pursuing the Comparison of Tones with Light, to say, that the intire String agitates at once every Kind of Fluid; and that this Combination of Vibrations produces the fundamental Sound, as, in regard of Light, White, compounded of all Sorts of Rays, establishes the fundamental Colour; and that we in general do not at all distinguish in this fundamental Sound the other Tones that compose it, any more than we perceive the various Kinds of Rays in White; but that the Ear of an excellent Musician is a Sort of Prism, that separates or distinguishes the Tones thus confused.

This

This Perfection of the Ear, superior to that of the Eyes, will be no ways astonishing to those who have ever remarked, that this Sense is more compleat in its Kind, than Vision is. For, without going any farther, the Hearing absolutely distinguishes all the Gradations of Sounds, determines them, reduces them to Calculation, and actually forms them into an Art. The Eyes cannot boast so much in respect of Light. They perceive in the Lump, that a luminous Body, a Colour, is more or less clear, or more or less deep, than another; and that is all. But the Quantity of this more or less they never will be able to determine.

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Hearing.

I shall now mention another Singularity of Sound rendered by Strings.

We have seen that the Moiety of an intire String sounds an Octave; and that likewise, on applying the Finger to the Middle of a String, this Octave will be produced in any Part of it touched by the Bow.

New fluted Sounds.

If, instead of resting the Finger firmly on the String, and the Neck of the Instrument, one touches the former but lightly, either with the Finger, or only with a Quieter, the Octave will be the same, as by applying the Finger hard, and even a more agreeable one: because both Parts of the String contribute to it at once, and the intire String touched never so gently, or if one ceases from Time to Time to touch it at all, mixes with it a little of the fundamental Sound.

Conse-

The
Hearing

Consequently, it is just as if one touched three Strings at a Time, in a State of Unison, which cannot fail of producing an harmonious Tone.

The Reason of this Singularity in Musick, is, because the simple Touch of the Quieter makes a Sort of Division of the String into two equal Parts. It is a small moveable Bridge, that separates the Vibrations of each Portion of the String, without interrupting in the mean while the Communication of these Vibrations. The String trembles under the Quieter; but the Vibrations of the intire String are thereby shortened, or, if you will, the first Class of ample and compleat Vibrations, which form the fundamental Sound, are suppressed, the String being only affected by the subaltern Vibrations of the Octave. What I here advance is in Supposition, that the Vibration of the fundamental Sound includes all the other Vibrations, which is really Fact. For when the Quieter touches the Middle of a String, you may make a double Octave sound on this String, without removing the Quieter from its Place. In order to this, first scrape strongly with your Bow, and you will give the String its fundamental Tone: because then the Force of the ample Vibrations, which form this Tone, surpasses the Touch of the Quieter, and renders it ineffectual. Secondly, push the Bow with less Violence, and you will sound an Octave, as we have intimated: because in that Case the Quieter suppresses one of the Classes of the

the Vibrations ; or because the Vibrations, being too feeble, lose against this Quieter one of their ^{The} ^{Hearing.} Classes, or a Moiety of their Quantity. The different Degrees of this Quantity, contained in the Vibration of a flat Tone, would they not be the first Cause of that Harmony, which Musicians distinguish in the sole fundamental Tone ? The Justness of this Explication appears confirmed by this other Experiment.

If you place your Finger to a Tierce of the String, and there rest it firm, it is evident you will sound a Fifth. But, if you there apply the Quieter, you will sound a Twelfth, or the Octave of a Fifth. Now if you rest your Finger afresh on this Place, and pass the Bow upon this Tierce of the String towards the Neck of the Violin, you will produce the same Sound, the same Twelfth, as resulted from the Quieter, when you passed the Bow upon the two other Tierces of the String. It is therefore the Sound of this Tierce of the String which you hear, when the Bow passes upon the two other Tierces. The Vibration of the Bow then passes from the two Tierces, which it touches, to the Tierce which is beyond the Quieter. This Quieter therefore does not at all intercept the Vibrations of the String : it makes only a Sort of Division, or Subdivision, on each Part of it. But what is the Reason that the Bow, which passes over two Tierces of the String, does not rather cause the Sound of this long Portion to affect the Ear,

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Hearing.

Ear, than that of the Tierce, over which it passes not at all? It is absolutely because this Tierce is shorter, that the Ear is rather affected by its Vibrations. These being shorter produce a sharper Tone. Now a sharp Tone is ever predominant over a Flat, and drowns it intirely.

The more you move the Quieter, either towards the Neck, or towards the Bridge, the sharper is the Tone; because it is ever the Tone of the short Portion of the String that strikes our Ears;

These Sounds are termed Fluted Sounds. Monsieur *Mondonville* calls them harmonious Sounds; and was the first who had the Courage to introduce them into grand Pieces, and the Address to make their Execution agreeable to the public Taste. We name these Sounds *Fluted*, because they have the soft and melodious Tone of the Flute. But they merit likewise this Appellation, inasmuch as they transfer to the Violin the Mechanism of the Flute; on which, it is well known, the same Hole is productive of several Octaves.

How quick soever the Vibrations of the Air are, that is put in Motion by the Body which produces Sound or Noise, they still take up a certain Time to communicate themselves, one after another, to the Air that is at a Distance from the Body which excites them. The Reason of this Delay is, because the Air, being elastic and porous, that which surrounds the sonorous

rous

nous Body gives way to the Pressure of this Body, and catches, if I may so express myself, in its Pores the Enlargement of it. This Air dilates itself afterwards in its Turn a little beyond its natural State, agreeably to the Disposition of all elastic Bodies. By this Means it communicates the Pressure it had just received to the Column of Air at a Distance: which Column of Air being confined, and afterwards enlarged in its Turn, acts in like manner, in regard of the subsequent Column, and so on successively. But this Succession of Pressure and Enlargement, from Column to Column, demands a certain Time.

One is convinced of this Truth on seeing a Gun discharged on a remote Plain. The Report of it does not reach the Ear, until a long Time after the Eyes have discerned the Flash. But it has been determined by exact Experiments, how much Time, Sound, or Noise, takes up in communicating itself successively, or what Way it makes in a given Time: and by the last of these Experiments, made by the Gentlemen of the Academy of Sciences, at the farthest Distances, it has been found *,

First, that the Report of a Cannon is propagated three Hundred and forty six Yards in a Second, and of course twenty Thousand seven Hundred and sixty Yards in a Minute. A League

* *Mercure de Juin 1738. Extrait d'un Mémoire sur la Propagation du Son, par Mr. de Cassini de Thury.*

The League being four Thousand five Hundred and
Hearing. Sixty four Yards, the Sound is conveyed every
 Minute four Leagues and a half, and two Hundred and thirty Yards. Consequently, it travels in an Hour two Hundred and seventy three Leagues, and one Hundred and eight Yards.

Secondly, that Sound is transmitted with the same Velocity, when it traverses a great Space, as when it runs over a smaller, without any Diminution.

Thirdly, that Sound is transmitted with the same Velocity in the Day-time as in the Night.

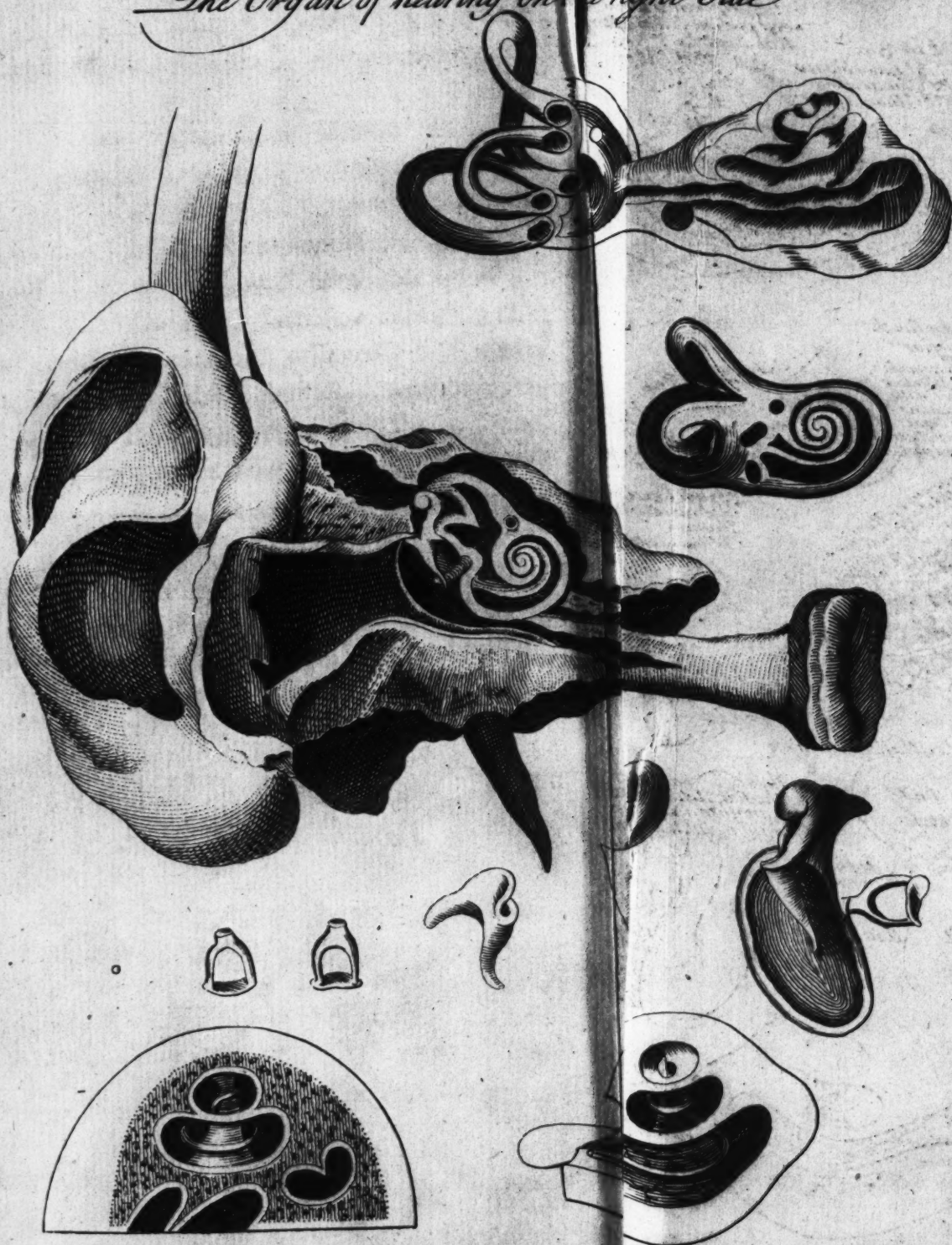
Fourthly, that there is likewise the same Velocity in rainy Weather, as when the Sky is serene.

Fifthly, that the Swiftneſs of Sound is equal, both when the Noiſe that produces it is great, and when it is ſmall; when the Mouth of a Cannon, for Example, is directed towards the Place, from whence the Report is made, and when it is pointed in a contrary Direction.

Sixthly, that the Velocity of Sound increaſes when the Wind ſets fair for it, and diminifhes when it is contrary, in Proportion to the Force of the Wind.

When the Vibrations of the Air, that produce Sound, ſtrike a Body of a certain Extenſion, they are reflected from under that Body to a particular Point, by preſerving their Modulation in ſuch a Manner, that the ſame Vibrations are

The Organ of hearing on the right side



Explication

the Labyrinth the Superior
or 3 Semicircular Canals

Fig. 1.
A general Plan of
the Organ somewhat
bigger than Nature. The

re. the thin or
squamous part
of the Temporal
Bone

*the External
right Ear.*

that part of the
containing the

Semi-arc
Canal

The Master of
Machinery since

The passage from
external to the
internal Ear

the Extremity of the
Nasoid process
or Apophysis

the Hiloid
process or
Apophysis

its Head
its Neck

its small
green (1)

1

its

11

The small Bo
of the Bar Articulated me
one another in their prop
situation with the Mem
of the Dr

the whole
form of
of over
of the
Temp

This is all much bigger than Nature the inferior fragment of the tape or string

the inferior fragment
of the lower of the

Os Orbiculare
or round Bone

*the inner Face
of y^e Ingots or Anvil*

Superior
back part
of D.

Fig. 5.
a section of the
Cochlea of a
mammal showing
the spiral
of the
Nerve

The double bottom of the internal Auditory Foramen or hole.

Fig. 3

Several times bigger
than Nature, from
M^r Duvernoy.

Cochlea or Cochlea

the
Fading

the middle one

the inferior

1.2. Opening where the
soft portion of the Auditory
Nerve enters the
Vestibulum

... of Variations ...

Dr. opening into 3 Tympanum of

Semicircular Canals
Superior

1. *Fenestra Rotunda*
or round Windows
2. *Fenestra Ovalis*

3. East of Canal
of the portio Dura.

called Petrosyn
of hearing call

Cochlea or Mail Shell

the Canal of S. P.
Dura, or had a po
of the Auditory

half Canal

Eustachius's Tube

Fig. 1
almost
large
as life

4 Spiral Canal of
Cochlea leading into
Drum.
5 D. leading into y^e Th

The
part
the

*the spiral winding of
of Cochlearia to the
D. to the D.*

Fig. of Capsicobolus

Fig. 4.
a deepening
of the
Blood Vessel
Membrane
the spiracles
being destroyed
except at Top and

S
E
o
in
n

are there repeated, tho' more languidly. This ^{The} Repetition, or Reflexion of Sound, is called an ^{Hearing.} *Echo*.

Several Echoes will result from a Place, ^{Reflexion} when there are several Bodies at different Dis- ^{of Sound,} tances, that reflect the Sound towards the same ^{termed an} Spot. The Reflexion of Sound, is governed al- ^{Echo.} most by the same Laws, as the Reflexion of Light, which we shall speak of in its Place. There is no Necessity for the reflecting Body being concave: A single Wall will produce an Echo: and I myself have known them rendered by convex Bodies, as well as by those of great Turnings and Windings.

The Organ and Mechanism of HEARING.

IN vain does the Air, agitated by sonorous Bodies, give us Shocks from all Quarters, if we are not furnished with particular Organs to receive its Impression. The Wind is felt by the Touch; but the Portion of Air that produces Sound, is of too subtile a Nature to affect this gross Sense, on which it makes not the least Impression.

The Ear is the Organ appropriated to this Sensation. I observed above, on the exterior Part of it, a Sort of Tunnel, like the broad End of a Trumpet, very well adapted to the collecting a great Quantity of Air. This Tunnel is much larger in certain Animals, as in the As

E and

The Hearing. the Hare. It is accommodated with Muscles that shut and open it on hearing, on which account these Animals have this Sense to a great Perfection. Man has also auricular Muscles, but they are of little Use for Want of Habit. There are those notwithstanding, who have the Motion of these Muscles no less than Animals; such, for Instance, was the celebrated Monsieur Mery*.

The Membrana Tympani. This exterior Tunnel is attended by a Canal ending in a Membrane, that is as it were the first Entry to the auditory Sinus's. This Membrane is stretched like the Head of a Drum, from whence it has obtained its Name. Its Centre sinks a little towards the first Sinus that is behind, and which is called the Tympanum, or **The Tympanum, or Drum of the Ear.** In this Sinus are a Sort of Springs or little Pullies, which terminate at one End in the Center of this Membrane, and at the other in the Entrance into the second Sinus, and are put in Action by Muscles. This Membrane and its Springs appear to have, in respect of the Hearing, the same Use, as the Pupil seems to have in Regard of the Eye. The Pupil is contracted or dilated in order to receive an Image in the greatest Perfection, and without the least Injury to the Organ. The Membrane of the Tympanum is extended or relaxed likewise

* A famous Surgeon of the Hotel-Dieu at *Paris*, and a Member of the Royal Academy of Sciences.

wise, to transmit to the Hearing the most perfect Vibrations, and such as are proportioned to this Organ. When the Ear is assaulted by the Impulse of too violent a Sound, this Membrane, whose Center is sunk towards its Sinus, is pushed outwardly by the Spring which terminates in its Center. By this Mechanism this Membrane is relaxed; which Relaxation diminishes so much of the Impetuosity of the Sound, as might be capable of hurting the Organ. At the same Time, and in Consequence of the same Motion, the Spring opposite to this, closes the Entrance of the second Sinus, and weakens also by that means the Impulse of the Air in this second Sinus.

On the contrary, when the Sound is too feeble, the first Spring draws the Membrane of the Tympanum inwards, and renders it more extended, and more susceptible of Agitation; the other opens the second Sinus, and facilitates the Action of the Undulations of the inner Air.

In Sounds, that are a Medium between the two preceding Extremes, the Membrane of the Tympanum likewise preserves a middle Tension; by which Conduct it is proportioned to these Sounds, and as it were in a State of Union with the Vibrations of the Air. Hence the trembling of this Membrane communicates the Sound to the inner Part of the Organ, in a manner more compleat and perfect. As the Pupil,

A Physical Essay

in a just Degree of Dilatation, transmits to the Retina a clear and distinct Image.

The first Spring destined to extend and relax the Membrane of the Tympanum, is composed of the little Bones called the *Malleus* and *Incus**, or the Hammer and Anvil: the second is formed of the same *Incus* and the *Stapes*, or Stirrup, joined together by the *Os Orbiculare*; and the Basis of the *Stapes* makes the Entry to the second Sinus. It is possible, that the Justness of the Ear in Musick depends partly on the Regularity of the Motion of the Muscles of these little Bones, in order to dispose exactly and readily the Membrane of the Tympanum to a Unison of the Tones it receives. One sometimes discovers in this Membrane a little Chink detected first by *Rivinus*.

Mistake of
some Ana-
tomists
concern-
ing Apes.

We read in the third Tome of *Observations de Physique*, p. 278, that, as Anatomists remark, Apes have not in the Ear the three small Bones we are speaking of. But I can assure the Public, that this is a Mistake. I have dissected a *Sapajou* Ape, and actually met with the Bones in Question. It is true, indeed, that they were in a manner hid, and sunk down towards the Sinus of the mastoid Apophysis; which is, perhaps, what has deceived those Anatomists.

Nevertheless, I do not at all assert, that the Membrane of the Tympanum, and those Bones

* Consult the Figures.

are absolutely necessary for hearing, but for the Justness and Perfection of it. This Membrane ^{The Hearing,} is also subservient to the preserving the Inside of the Ear from the Injuries of the Air, and exteriour Bodies. The Necessity of these Organs is evinced from Experience. On breaking the Membrane of the Tympanum of a Couple of Dogs *, those Animals heard well in Appearance, but became deaf a little while after.

These little Bones of the Ear acquire no manner of Accretion, being of equal Size in Infants as in Adults; because, perhaps, they are extremely hard, and detached from all others, and the Membrane that invests them is so thin, that one of the greatest Anatomists of the Age imagined they had no Membrane at all.

The first Cavity of the Ear contains, besides these Machines, a subtile Air, which ^{Inner Air of the Ear,} it receives from the Bottom of the Throat, by a Canal, called *Eustachius's Tube* †, the broad Part of which opens itself towards the Place of the Communication of the Nose with the Mouth. It is by this Passage of the Air, and the Perforation observed by *Rivinus* ^{How some Smokers force the Fumes of their Tobacco thro' their Ears.} in the Membrane of the Tympanum, that some particular Smokers, by stopping their Nose close, and shutting their Mouth, discharge the Fumes of their Tobacco by the Ear. This in-

E 3

ward

* Observ. Physiq. Tom. II. p. 200.

† A great Anatomist, from whom this Canal derived its Name.

The
Hearing.

ward Air, introduced by *Eustachius's* Tube, supports the Membrane of the Tympanum ; and is what, being agitated by the external Air, communicates its Vibrations to the immediate Organ of hearing.

This immediate Organ, is contained in two other Apartments, each of them furnished with an Entry to the Drum, or first Cavity. This Cavity is, as it were, the Antichamber to those Apartments, which have besides between them another Entry of Communication. These Entries are likewise provided with Membranes. Nothing is so adapted to the putting all the Air in Motion, that is contained in these Sinus's, as the Membranes extended at the Entrance into them. The Drum and Kettle-Drum are Instances of this.

One of these Apartments is termed the *Labyrinth*, the other the *Cochlea*, or *Snail*.

The Labyrinth consists of a Vestibulum, from whence issue three semi-circular Canals, which form a little more than a half Circle, and then return to the same Vestibulum. The three Canals are particularly stiled the Labyrinth. I conceive that the Air, being pushed along the Vestibulum, and the Orifices of these Canals, the Vibrations of it that have insinuated themselves into each of those Orifices, must of course meet one another in the middle of each Canal, and there produce a Collision intirely accommodated to the exciting a Trembling, or Vibration

in

in those Canals, and the nervous Membrane that lines them: From this Impression results the Sensation of Hearing.

As this Labyrinth is simple and uniform, I conclude it is the general Organ of hearing, that is to say, the Organ that is agitated indifferently by all Sorts of Sounds or Noises; or, if you will, it is the general Organ of Noise. But the Cochlea seems to me to have a Construction and Use more refined. Its Figure resembles in Reality the Shell of a Snail. Its Inside is composed of two Windings, or of two Sorts of Spiral Canals, and separated from one another by a thin and nervous Membrane, supported by the jutting out of bony Laminæ.

The Artifice of this Construction is of the most perfect Mechanism. The essential Property of an Organ of Sensation, is to be proportioned to its Object, and, in respect of the Organ of hearing, to be capable of being in Unison with the different Vibrations of the Air. These Vibrations infinitely differ, and have a Progression susceptible of Degrees infinitely small. It is necessary therefore that the Organ, formed to be in Unison with all these Vibrations, and to receive their Impression distinctly, should consist of Parts whose Elasticity is correspondent with this same Progression, this same insensible and infinitely small Gradation: Now the Spiral is in Mechanics the sole Machine productive of this insensible Gradation.

The
Hearing.

It is evident, that the spiral Lamina of the Cochlea is intirely formed to be set a trembling by the Impulse of the interiour Air that surrounds it. It is manifest likewise, that the Lamina making, at the Basis of the Spiral, a greater Compass, has of course longer Vibrations, and that it has very short ones on its Top for a contrary Reason. Ply a Piece of Wire in the Cochlea, and you will find to what a Degree the great Windings will be put into Motion, and how stiff, on the contrary, will remain the small ones on the Top, or in the Center. Now from the Beginning of the Basis of the Spiral, where the Lamina is most supple, to the Extremity of its Summit, where subsists its last Degree of Rigidity, there is an insensible or infinitely small Gradation of Elasticity: inasmuch that whatever Division is conceivable in the Tones, there is no one Sound at all that does not meet, in the Points of this Spiral, its Unison, or corresponding Vibration: So that there is no Tone unable to imprint distinctly its Vibration on this Spiral, and in this consists the grand Artifice of the Cochlea. It is for this Reason I look upon the Cochlea as the Sanctuary of the Hearing, as the particular Organ of Harmony, and of the most distinct and most delicate Sensations in this kind.

Now Birds
are Musi-
cians.

Birds, you will object, have no Cochlea, and are nevertheless the most musical of the whole Creation. Birds have an exquisite Hearing, tho'

not

not furnished with this Contingency, because their Heads are almost intirely sonorous like a Bell: which is owing to their not being involved in complicated Muscles as are the Heads of all other Animals. Hence must they necessarily be agitated by the Sounds which present themselves. Their Labyrinth being very sonorous, is sufficient for this End. The most simple Grott will echoe back a musical Air: but if to this excellent Disposition of hearing in Birds, Nature had added the Cochlea, they would have been much more sensible of harmonious Modulations. They would have had a Passion for Harmony, as almost all Animals have for gormandizing: which is not the Case. For one ought to recollect, that the musical Quality peculiar to Birds, proceeds less from the Delicacy and Taste of their Ear, than from the Disposition of their Throat. They, furthermore, in this particular resemble Musicians, who give Pleasure to others, without partaking of any themselves. We hear a Dog howl, we see him weep, as it were, at a Tune played upon the Flute; when, on the contrary, this Animal is all alive in the Field, at the Sound of a French-Horn. The Horse takes Fire at the Sound of a Trumpet, in spite of the thick muscular Texture his auditory Organ is encompassed with. Without the Cochlea these Animals are provided with, one would by no means discover in them this Sensibility for Harmony. We should

rather

The Hearing. rather find them, in this Respect, as stupid as Fish, which are destitute of the Cochlea, as well as Birds; but without the Advantages which Birds have of a Head sufficiently disengaged, sufficiently sonorous, to supply this Defect.

Stupidity of Fish.

The Power of Musick.

Man unites all these mechanical Perfections, and moreover adds to them those delicate and refined Sentiments, which distinguish him from other Animals. It is this above all things on which depends his great Sensibility for Harmony. For that is good Musick, which expresses Sentiments, or excites them. It was in this kind of Musick the Antients excelled. Witness the following Instance in one of Alexander's Musicians * :

*Hear how Timotheus' varied Lays surprise,
And bid alternate Passions fall and rise !
While, at each Change, the Son of Libyan Jove,
Now burns with Glory, and then melts with Love.
Now his fierce Eyes with sparkling Fury glow,
Now Sighs steal out, and Tears begin to flow.
Persians and Greeks like Turns of Nature sound,
And the World's Victor stood subdued by Sound !
The Pow'r of Music all our Hearts allow : &c.*

This, which *Timotheus* produced in the Heart of *Alexander*, was no surprizing Phænomenon among the Antients. It was the ordinary Effect of their kind of Musick †. Nor did they at

* *Pope*, in his Essay on Criticism.

† See *Monf. Rollin*, Tom. II. Page 215.

all confine it to mere Diversion, but employed ^{The} it in the most serious public Affairs, and made ^{Hearing.} it a Part of their Politics. It was not only introduced in their theatrical Declamations, but used also in their Harangues, to a Degree of Prostitution. And it was partly by the Power of Musick, that they transported the Hearts of the People, or the Soldiers, either with the Love of Peace, or Eagerness for War.

Our famous *Lulli* seemed to have it in his View to revive this pathetic Musick, these Sounds that penetrate to the Heart. And perhaps the *French* Masters might accomplish what that extraordinary Man only began, did they not run so much after *Italian* Cascades, Music that rather surprizes, than touches the Passions.

What I here advance concerning the modern Taste, is, notwithstanding, no general Rule. We have still in *Europe* Musicians and Players on Instruments, that are studious of good Music, and excel in it. It is but a very little while since there was at *Venice* an Artist, who, by playing on his Lute, inspired his Audience with what Passion he pleased. The Doge had a Mind to have a Specimen of his Powers. The dextrous Musician determined his Soul successively from Melancholy to Joy, and from Joy to Melancholy, with so much Art and Energy, that the Doge, remaining no longer Master of his

The his own Affections, ordered him to give over
 Hearing. his Inchantments *.

Musick
 conducive
 to Health.

This Power, which Musick has of moving the Soul, and by her Means the whole Machine, renders it very conducive to the Recovery of Health. And this Effect of it would be easily conceived, were we to reflect what Connexion there is between these two Parts of the human System. The Generality of Disorders consist in an Alteration of the animal Fluid, and its being affected by perverse Modifications. This Fluid is the Soul of Sensations and Passions; and it is owing to the Organs that it receives the Impressions of Objects, and takes the greatest Part of its Characters and Modifications. The Senses then are Organs very well adapted for changing the Character of this Fluid, and consequently of exciting in the whole Machine, which it animates, happy Revolutions. Now of all the Senses the Hearing is that which gives Man a Preheminence above all other Animals with Respect to Harmony: There is no Sense which causes in him such Emotions as this.

It is therefore no matter of Astonishment, that an exquisite Musician, seized with a continued Fever and Delirium, should be cured by good Musick †; nor that a Dancing-Master, attacked by a violent Fever, Lethargy, and Madness has recovered his Senses and Health by the same Means.

Every

* L' Existence de Dieu démontrée, pag. 171.

† Histoïr. Acad. 1717.

Every Body knows the Story of the Cure of ^{The} *Saul*, by the Harp of *David*, and few Persons ^{Hearing:} are unacquainted with the History of the *Tarantula*. The Sting of this Sort of Spider is not more painful than that of a great Ant, or of a Bee; but still it is attended with very dangerous Symptoms, such as Melancholy, Suffocation, Lethargy, Delirium, and even Death. Musick is the only Remedy for this terrible Evil. The Method is to send for a skilful Musician, who plays different Tunes upon different Instruments; for all Sorts will not answer the Purpose. The Instruments that succeed best are the Bagpipe, the Tambourin, Guitar, Lute, and Violin. The favourite Tunes are those that are gay and lively.

When the Musician has pitched upon the salutary Instrument, and hit upon the Tune, he perceives the lethargic Patient to move, agreeably to the Time and Cadence of it, first a Hand, then an Arm, and successively his whole Body. After which he betakes himself to dancing with an astonishing Activity, and that sometimes for six intire Hours together. When they see him tired, they put him in a warm Bed, and when they think he has been sufficiently reposed, the Musician attacks him with a new Saraband. This Exercise is continued, until they find the Patient tired, and that he begins to appear sensible.

These

**The
Hearing.**

These Signs of Cure shew themselves generally at the Expiration of seven or eight Days. Then the Patient fancies himself to have come out of a profound Sleep, without any Idea either of his Illness, or the Jiggs he had been performing. Sometimes his Disorder leaves behind it a deep Melancholy, and sometimes likewise the Fit returns annually; in which Case there is a Necessity of recurring afresh to Musick.

**Why the
Bones of
the Ear do
not grow.**

It is observable, as to the Organ of hearing, that the Labyrinth and the Cochlea do not at all increase in Size any more than the little Bones. They are as large in Infants as in Adults, altho' the external Bones of the Ear acquire a considerable Growth and Hardness. The Reason is, because the exterior Bones are invested with a Periosteum well supplied with Nourishment, while the inner are divested of this Nourishment; and besides, the Bones are there of a Solidity that would even render it impracticable to receive any Nutriment, were it conveyed to them. One of those Authors who make it their Study to fish out Miracles on all Occasions, assigns no other Reason for this Phenomenon, than the Will of the Creator; who, contrary to the ordinary Laws of Nature, has established the Bones of the Ear in a State of Non-accretion; that, as there was no Difference in regard of the Organ in Infants and Adults, there should be no Diversity in the Impressions that Sound should make either on these,

these, or those. He assures us, were the Hearing to increase, like the Growth of other Organs, Children as they advanced would receive this Impression of Sounds in a different manner, and consequently at a certain Age would no longer know the Voice of their Parents. This Author meant, that they might find an Alteration in their Parents Voice; but could never imagine they should not know it to be the Voice of their Parents, as in that Case those Children must have been blind. So that this Decree of the Almighty would then have been solely made for blind Children. But with what Foundation can we suppose that the Accretion of the Bones of the Ear should make an Alteration in the Sensation of Hearing? The Organs of Sight, Taste, Smell, do not these acquire Growth without disconcerting those Sensations? And tho' the Hearing be not susceptible of making the like Advances, must one conclude from thence, that this Organ is the same in all Subjects? This is no ways probable. Every one hears therefore after his own Mode, as is evident, and feels and tastes likewise proportionably to the particular Structure of his Organs.

The
Hearing.

Nothing in the mean while goes on at all the worse. Wherefore let us revere the Designs of God, rather than dive too far into them; lest, with the laudable Intention of publishing his wond'rous Works, we make him an Offering of

The Hearing. the Folly of our own Imaginations. He has subjected the Universe to our Researches, to our Reasonings; but not that we should call his Decrees in Question; and make him think and act agreeably to our weak Understandings. When we attempt this, methinks I hear one of *De la Fontaine's* Insects descanting on the sublime Geometrical Operations of our *Descartes*, our *Newtons*, or on the profound Politics of our *Colberts*, and *Fleurys*.

Structure
of the Ear
in order to
receive all
Impres-
sions of
Sounds.

Of all the Organs of Sensation we have run over hitherto, we have seen that their Structure is contrived for the Penetration of their Object, and the Conveyance of its Impression, and for its being, as it were, absorbed in order to make a more perfect and compleat Impression. This very Mechanism subsists also in the Organ of the Hearing. Every thing concurs to facilitate the Entrance, and to establish the Retention of the Impression of sonorous Vibrations.

The exterior Tunnel collects these Vibrations. The next Tube, which conducts this agitated Air, discovers some oblique Sections at the bottom Parts of it made by the Membrane of the Tympanum. This Obliquity is the Cause why, on the rebounding of the exterior Air from under the Membrane of the Tympanum, it immediately rushes against the opposite Side of the Tube; from whence it is again reflected under the same Membrane to which it communicates all its Vibrations.

Were

Were this Tube strait, and perpendicular to the Membrane of the Tympanum, the exterior Air would be reflected from under this Membrane out of the Tube of the Ear, and consequently would have a much less Effect. The Hearing.

In like manner the inner Air is shut up in the Sinus's by Membranes. The Vibrations it receives from without, enter on one Side the Orifices of the Labyrinth, and on the other those of the Cochlea. The Vibrations that insinuate themselves into the Orifices of the Labyrinth, tend to make a reciprocal Collision amidst the semicircular Canals; by which Action all their Effect is in a manner absorbed in these Canals. Not that I imagine their Impression is confined to the Point where this Collision is made, as the Rays of Light cause an Impression where they are united; because the Mechanism of these two Sensations is absolutely different. Here it is, a painted Image, there Vibrations, a Trembling; that communicates itself to the whole Organ by the very Collision that is made in several Points.

The Orifices of the Cochlea are twofold. One of them communicates with the Labyrinth or its Vestibulum, and is the Entrance of the internal winding; the other opens itself directly in the Drum, or first Sinus, and is the Entrance of the external Winding. The Vibrations consequent to these Openings are propagated the whole Length of the Spiral. But being arrived

F

at

The
Hearing.

at the Top, at the Extremity of the Cochlea, they undergo a Collision both against this impervious Extremity, and amongst themselves, and thereby give a Shock to all this Organ, particularly to the spiral Lamina, that Portion of it especially which is in Unison with the Vibration. So that all the Parts of the sonorous Vibrations are extinguished in the Organ of Hearing, in such a manner as to leave behind them all their Impression.

The inner Air of the Drum is supplied by *Eustachius's* Tube; but the inward Air of the other Cavities is conveyed to them either by the Porosity of the Membranes that cut off their Communication with the Drum, or by the Fluids that circulate in the Periosteum of the Cavities.

We hear
best with
the Mouth
open.

It is remarkable that we hear best with the Mouth open. The Reason of it is, because not only the Vibrations of the Air are communicated by the Mouth and *Eustachius's* Tube to the Inside of the Ear, but moreover, because the Joint of the Jaw-Bone, placed against the Tube of the Ear, retires from it on opening the Mouth, and by that Means leaves this Passage more at Liberty.

An Instru-
ment for
relieving
Hardness
of Hear-
ing.

The Structure I have been observing in the Ear, leads me to the Invention of an Instrument formed for supplying that Sort of Defect called *Hardness of Hearing*. My Machine consists of two Parts. The first is a Horn Shell

that retains a good deal of Air, and is exactly fitted to the Tube of the Ear; the other Part is a Tunnel inserted at the Center of the Shell.

The
Hearing.

This Tunnel receives a good deal of exterior Air, put in Motion by those that are speaking. The Vibrations rush in Crowds, as it were, into the Shell, and communicate themselves to a vast Space of Air which it contains; and, being there retained and reflected by the vaulted Parts that surround the Tunnel, are obliged to unite themselves universally towards the Inside of the Ear, where they make a very strong and powerful Impression. The Figure of the Instrument exhibited in Plate IV. Fig. 4. points out the Nature of it more effectually than could be done by the most elaborate Description.

The nervous Organ, which immediately receives the Impression of Sound, is an extremely fine Expansion of the seventh Pair of Nerves, that line all the Inside of the Organ of Hearing. This Nerve has two Parts, one soft, that is expanded in the Cochlea and Labyrinth, and one hard, which distributes some interwoven Filaments to the Tympanum, or Drum, that pass behind the Membrane of the Tympanum, and make what is called the Cord of the Drum. But the greatest Portion of this Nerve is distributed in the Parts of the Face.

The Hearing is one of the most valuable Senses, and the Loss of it may be ranked in the Number of the greatest Misfortunes. Tho' the

The
Hearing.

Taste be only absolutely necessary for Life; (for there is but little Difference between the Taste and Appetite;) yet Life, deprived of Sensations so useful as Hearing; is a kind of premature Death.

I must nevertheless agree with those who look upon Deafness, that is not from one's Birth, as an Accident less grievous than Blindness.

Utility of
Hearing
compared
with that
of the
Sight.

There are in the World more Objects of the Sight, than of the Hearing. And besides, Understanding is conveyed by the Eyes, not only by means of Writing, Books, &c. but also by Attitudes, Signs, and Motions of the Lips, Eyes, and Visage of those one beholds: witness the Pantomime Pieces so much in Fashion upon the *English* Theatre; and even in some Degree at this Time in *France*. It is certain, that the Sight is a Supplement to the Hearing, much more eminently than Hearing is to the Sight. The World abounds with deaf People whom we make to understand what we please. In the

Deaf that
understand
by the Mo-
tion of the
Lips.

Year 1700 there was a Merchant's Wife at *Amiens*, who comprehended all that was said to her, by solely attending to the Motion of the Lips of whoever spoke to her. She joined in this manner in the most uninterrupted Conversations; which did not produce half the Fatigue that the ordinary ones by Speech are apt to create: For one might be dispensed with in regard of the Articulation of Sounds, it being sufficient to move the Lips as one does in speaking.

ing. Thus she understood very distinctly, and would immediately tell you of it, in case you spoke a strange Language to her *. There is recounted another Instance somewhat like this †.

A Person born deaf is unavoidably dumb. For in order to speak, it is necessary to learn a Language; and, to learn a Language, it is requisite to hear. It is very perceptible that this Class of deaf People are for the most Part deprived of the Advantages and Consolations we have remarked in the ordinary deaf. A Man deaf from his Nativity is, in my Opinion, a great deal more unhappy than one born blind. To form a right Judgment of his excessive Misery, we need only reflect how valuable to Mankind are the Lights of Education, of which this Species of deaf Persons is almost totally deprived. We have remarked, that there are more Things in the World that are the Objects of the Sight, than of the Hearing: but, in point of Knowledge, there are very few Truths that present themselves to the View, being almost universally the Objects of our Hearing. We have, indeed, arrived at the Dexterity of teaching a Person deaf and dumb to read and write. Deaf and dumb By pointing, for Example, to a Candle, and taught to writing down that Word, we shew that this is read and the Mark peculiar to that Thing; which he write.

F 3

will

* Observ. de Physiq. Tom. II. p. 209.

† Ib. Tom. III. p. 279.

The
Hearing.

will recollect whenever you display to him that Character. One may teach him likewise the Names of his Friends, or rather the Figures that distinguish them. But who is not sensible how limited this Art of Signs is without the Help and Concurrence of Sounds? You make a deaf and dumb Man acquainted with a great Number of Substances, or Names of Things; but what Method will you take to apprize him of all the Appellations assigned to these Things? How will you make him comprehend the Verbs, their Moods, and Tenses? The Acquisitions, in Point of Knowledge, of this Class of Mortals, are confined to Matters intirely visible, and consequently are extremely limited, what Pains soever one takes to instruct them, and in spite of their natural Sagacity in guessing at the least Sign. We may judge of this Affair from the Account recorded in the History of the Academy of Sciences, of one deaf from his Nativity.

A young Man of about five and twenty Years of Age, born deaf and dumb, began all on a sudden to speak, to the great Astonishment of the whole Town of *Chartres*, where this singular Event happened. He gave out, that four or five Months before, he had heard the Sound of Bells, and was exceedingly surprized at this new Sensation. After this a kind of Water gushed from his left Ear, and he heard perfectly well with both. He continued in this State

State three or four Months without uttering a Syllable, accustoming himself to repeat in a quite low Voice the Words he heard, and confirming himself in the Pronunciation and Ideas appropriated to those Words. At length he determined on breaking Silence; and accordingly began to speak, tho' his Accents were yet but imperfect. Some intelligent Divines soon got about him, and put Questions to him concerning his past State, which turned principally on God, on the Soul, on the moral Goodness or Evil of Actions. He did not seem to have carried his Thoughts thus far, tho' born of Catholic Parents, accustomed to attend at Mass, and taught to make the Sign of the Cross, and to kneel in a praying Posture, which he had never accompanied with any one single Intention: so true it is, that the greatest Source of human Ideas springs from their reciprocal Commerce. I have given this Relation in the very Words of the Academy,

Of the SIGHT.

AMONG the Senses there is no one so useful as the Sight ; nor is it useful only, but likewise universally confessed to surpass them all in Point of Beauty and wonderful Effects. The Province of celebrating its Charms, I leave to the Poets. Its surprising Properties alone belong to me as a Naturalist ; and, indeed, what Naturalist could avoid being enchanted by them ? The Mechanism of Vision has something in it miraculous. Its Organ is a Prodigy of Dioptrics *, which the most consummate Art must fall vastly short of imitating. Light, which is its Object, participates of a Sort of middle Nature between Matter and Spirit †. It is at least the purest Substance the Soul receives the Impression of by means of the Senses ; and consequently the Sight is, if I may so express myself, the most spiritual of them all.

Mechanism of Vision a Miracle of Nature.

Sight the Mirror of the Soul. Even the common Herd of Mankind look upon the Organ of Sight as the Mirror of the Soul. It is in the Eye, where ordinarily every one's Characteristic is legible, and predominant Passion

* Dioptrics are a Part of Optics, which treats of the Passage of Light across transparent Bodies.

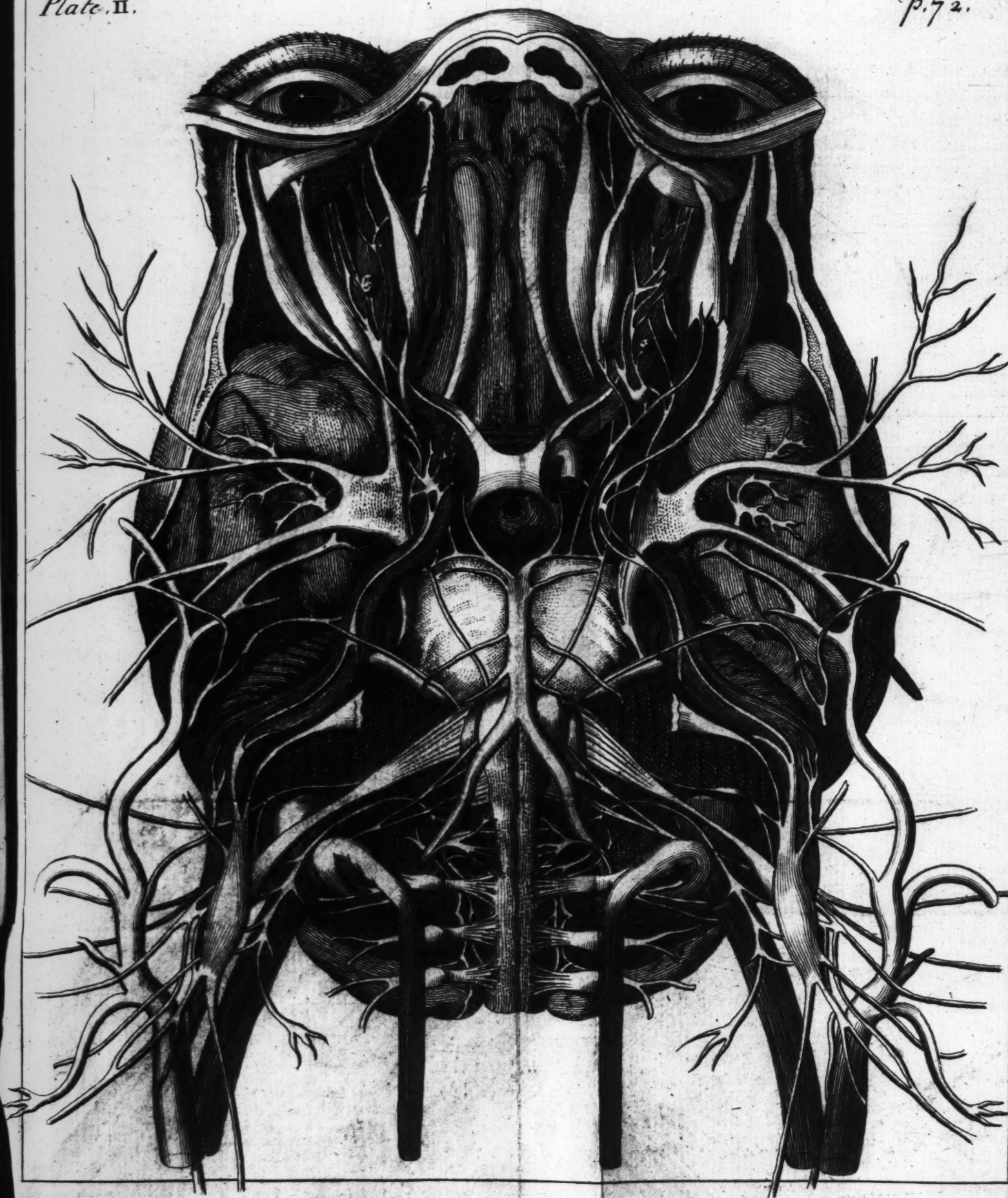
† Mémoire de Mde. *De Chatelet*, sur la Nature du Feu, pour le Prix de 1738. p. 97.

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The Basis of the Brain with its Appurtenances as large as Life

Plate. II.

p. 72.



Explanation of the Plate

- A Fore Lobes of the Brain
- B Middle Lobes
- C Posterior Lobes

- Δ a Portion of γ Pia Mater
- 1. Olfactory Nerve 1st pair
- 2. the Optic Nerve 2nd pair
- 3rd pair or Motor: Oculorum
- 4th pair
- 5th pair, 6th pair
- 7th pair or Auditive portio. Nottis thick portio dura thin
- 8th pair or par vagum, or middle Sympathetic
- 9th pair, or Lingual
- 10 pair to the Neck
- 11, 12, 13. the Cervical pairs
- g Intercostal Nerve
- e, f. their Origins which join upon γ Carotide in the Cavernous sinus

- places where the Nerves & Arteries perforate the Dura Mater
- * the Anastomosis of γ Lingual Branch of γ Maxillary inferior with γ Portio Dura a little before its exit from the Ear

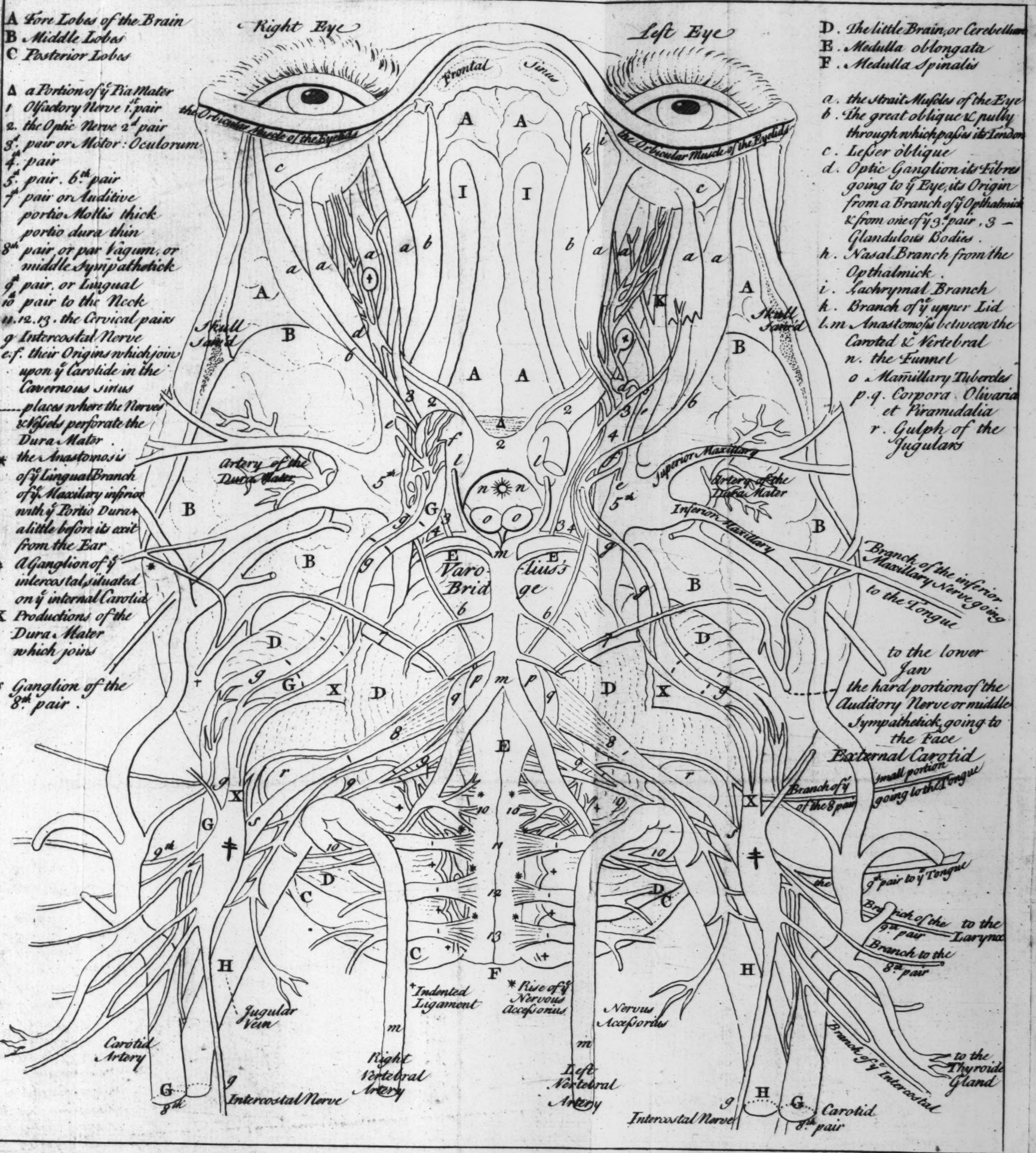
- * A Ganglion of γ intercostal situated on γ internal Carotide
- X Productions of the Dura Mater which joins

- s Ganglion of the 8th pair

Right Eye
Left Eye
Frontal Sinus
Orbicular Muscle of the Eyelids
Skull Suture
Artery of the Dura Mater
Superior Maxillary
Inferior Maxillary
Branch of the inferior Maxillary Nerve going to the Tongue
to the lower Jaw
the hard portion of the Auditory Nerve or middle Sympathetic going to the Face
External Carotid
Branch of γ of the 8th pair going to the Tongue
the 9th pair to γ Tongue
Branch of the 9th pair to the Larynx
Branch of γ Intercostal to the Thyroid Gland
Carotid Artery
Jugular Vein
Intercostal Nerve
Right Vertebral Artery
Left Vertebral Artery
Nervus Accipitrinis
Indented Ligament
Rise of γ Nervous Accipitrinis

- D. The little Brain, or Cerebellum
- E. Medulla oblongata
- F. Medulla Spinalis

- a. the Strait Muscles of the Eye
- b. The great oblique & pulley through which passes its tendon
- c. Lesser oblique
- d. Optic Ganglion its Fibres going to γ Eye, its Origin from a Branch of γ Ophthalmick & from one of γ 3rd pair, 3 - Glandulous Bodies
- h. Nasal Branch from the Ophthalmick
- i. Lachrymal Branch
- k. Branch of γ upper Lid
- l, m. Anastomosis between the Carotid & Vertebral
- n. the Funnel
- o. Mamillary Tubercles
- p, q. Corpora Olivaria et Pyramidalia
- r. Gulph of the Jugulars



Passion painted; inasmuch as this Organ, entirely nervous, and very nearly bordering on the Brain, abounds with Spirits, which must necessarily express the respective Dispositions.

The
SIGHT.

Of LIGHT.

LIGHT, the Object of Vision, is an extremely subtile Matter. This is an incontestable Point, which is sufficient for our Purpose. It is not very material how its Parts are fashioned: its prodigious Subtility is demonstrated by the surprizing Facility with which it penetrates a Diamond, a Body of the greatest Solidity and Gravity, and the least porous of any Substance in Nature.

Light a
very sub-
tile Mat-
ter.

What we term Rays of Light, are the small Filaments of which Light is composed, and also the elementary Particles, or the Corpuscles that constitute those Filaments, and which form the Matter of Light.

Rays of
Light.

This luminous Matter is expanded all over the Universe, and all other Species of Matter are impregnated with it, somewhat like the Earth's being moistened with Water. The Sun is a Lake, a Sort of Ocean, where this Matter is amassed in greater Quantity, that is to say, with less of Mixture. Perhaps even this Light of ours is of a more subtile Nature, and softer than that of this Lake, according to the general Law established in the Formation of the

Light uni-
versally
expanded.

The
SIGHT.

the Universe, that the heaviest Bodies should ever occupy the Center of a Vortex. The Difference then that subsists between Light and Fire is only this; that in Fire the Parts of this subtile Matter are more massy and more agitated.

Luminous
Matter not
so massy as
that of
Fire.

That the Matter of Fire is more massy than that of Light, is evinced by Experience. In the middle of the torrid Zone, on the Top of the *Cordeliers*, (Mountains elevated above the Clouds, Wind, and Mists) where of Course Light, and the Sun that animates it, ought to be endued with great Force, Cold, notwithstanding, is there as excessive as in the North Seas*, proving mortal to those who are not guarded against its Intensity. But who would imagine there could be a Possibility of running a Risque of dying by Cold on a Mountain in the torrid Zone? Now from whence proceeds this terrible Extreme, in the midst of a Region formidable by reason of its Heat?

By the just-recited Law, subtile Matter is so much the less subtile, and of so much more sensible Efficacy in regard to us, as it is nearer the Center of the Vortices; and it becomes so much the more subtile, dissolved, and inefficacious in Proportion to its Distance from this Center. That which penetrates the Earth, and our Atmosphere, is governed by this Law.

The

* Abridgment of the Philosophical Transactions, Vol. V. p. 147. or Le Spectacle de la Nature, Tom. IV. p. 199.

The Summit of the *Cordeliers* being extremely elevated in the Atmosphere, the Action of the Sun in this Region only puts in Motion a very subtile Matter, that is but one Degree beyond pure Light. Now the Impression of such a Matter is reserved for the sole Delicacy of the Sense of seeing. But, in respect of our other Solids and Fluids, this Matter makes its Way freely, and penetrates them almost without at all affecting them, its Motion dying away irresistably, and without the least Agitation of the Parts. As it cannot then make any material Impression on them, a Cessation of Motion in our Fluids necessarily ensues, as the principal Part of their Motion is owing to the Fluids of the Universe which penetrate them; and, in short, a total Stagnation of the Blood and Juices, with the Death of the Animal, follows. It is to the same Cold of mountainous Regions, we must ascribe the Origin of Hail, that is to say, of congealed Water, which falls sometimes at *Midsummer*.

The
SIGHT.
Why several have died of Cold on the Top of the *Cordeliers*, tho' in the Torrid Zone.

In a less elevated Region, as on the ordinary Surface of the Earth, we meet with a Matter less subtile, more massy, and capable in a greater Degree of affecting our Fluids and Solids, of rarifying both the one and the other, and of producing those Motions and Agitations, called *Heat*. And these Effects would be still more considerable, were the Agitation of this Matter increased by the Action of the Sun.

Hail falling sometimes in Summer accounted for.

Cause of Heat.

If

The
SIGHT.

Central
Fire.

If we descend below the Surface of the Earth, and penetrate into the Bowels of it, even to those subterraneous Caverns where the Sun's auxiliary Action can have no Access, at least directly, we should notwithstanding by no means incur the Hazard we should be exposed to on the mountainous *Cordeliers*; as the Bulk and Solidity of the subtle Matter, and its inherent Motion, that receives an Augmentation the nearer it approaches to the Center, supply the Loss on the Part of the Sun. It is this fiery Matter diffused in the Entrails of the Earth, that constitutes the central Fire, so analogous to the Caustic Fluid established in the animal Economy. It is that which renders Places under Ground hot in Winter*, and the more so the deeper they descend, according to the Experience of Monsieur *Mariotte*. And as both Men and Beasts have been killed by the Cold, and found in a manner petrified, on the Top of the *Cordeliers*; so, on the contrary, several have died by Heat, and become in a manner dissolved in Caverns of the Earth of an extreme Depth.

Matter of
Light finer;
and softer
than that
of Fire.

The Rays transmitted to us from the Moon, is a farther Proof that the Matter of Light is a great deal more subtle, and much finer, and softer,

* Subterraneous Places are equally hot in Summer. From the Heat of Summer it is, that one finds them cold at this Season of the Year, as it is the Cold of Winter, that makes them feel hot. But in Reality, this Heat is the same at all Seasons, because the Central Fire is ever the same.

softer, than that of Fire, and very little capable of producing the Effects of that Element. ^{The} Monsieur *De la Hire* the younger, during a fine ^{SIGHT.} full Moon, exposed to the Rays of this Planet ^{Experi-} the great Burning-Glass of the ^{ment of} *Observatoire* at ^{Monf. De} *La Hire*. *Paris*; and applied to its Focus the Bulb of *Monf. Amontons's* Thermometer, which is endued with the greatest Sensibility, if one may use the Expression; of any we have. The Mercury rose not at all; altho' by this Glass the Rays were collected into a Space three Hundred and six Times smaller than their natural State; when they ought consequently to increase the apparent Heat of the Moon by so many Degrees. The *Urania* of our Age *, so versed in these sublime Experiments, adds, that the Rays of the Moon thus united, are more dense and compact than those that issue from a Wax-Candle; tho' this Candle nevertheless burns with a lively Blaze, and these Rays of the Moon cannot so much as imprint the least Sign of Heat even on an Instrument susceptible of her lightest Impressions. Whence it is evident, that the Matter of Light is different from that of Fire and Heat, and a great deal grosser.

But how comes the Burning-Glass of the *Palais-Royal*, in assembling a great Quantity of ^{Why the} Rays in a small Space, to produce the most terrible Fire imaginable; a Fire, that in an Instant ^{Burning-} puts in Fusion the most compact Substances, such ^{Glass of} as ^{the Palais} ^{Royal} melts Gold and precious Stones.

* Mde. Du Chatelet, loc. citat.

The as Gold and precious Stones? **The Reason is,**
SIGHT. because this great Quantity of Rays is intimately united to the Matter of the Fire that is in the Atmosphere; which being borne and animated by these Rays, is crowded jointly with them in the Focus of the Glas, and there works the prodigious Effects in regard of which Light is only the Soul, or first Mover.

Tho' this luminous Matter be universally diffused, it does not alwas manifest itself, at least to ordinary Eyes. It has a Motion, like all subtile Fluids; but this Motion is not of Energy sufficient to make an Impression on our Sight: or rather, the Motion it partakes of as a Fluid, is not that which it ought to be endued with, as an Object of Vision. The Air is therefore incessantly in Motion as a Fluid: but, in order to produce Sound, it is necessary it should be furnished with the supernumerary Motion of Vibration, or Undulation, it receives from sonorous Bodies. In like manner the Matter of Light, besides its Motion of Fluidity, necessarily requires Vibrations excited either by the Sun, or the Stars, Fire, or in short by some luminous Body, whatever it be. These Vibrations are always made in a direct Line.

Vibrations necessary to luminous Matter.

The Sun is generally acknowledged to be the most powerful Mover of this Matter. Consequently its Absence involves it in Darkness, not because the Force it acts with upon this Matter is absolutely confined to the Parts it pushes

pushes in a strait Line; the neighbouring Particles are likewise agitated, which is partly the Cause of Twilight. It is also the Reason why we see a Solar Ray that darts into a dark Room, tho' one be sideway, and at a Distance from the Ray. But, in Proportion to the Distance of these Particles, this Communication of Motion becomes so feeble, that at last this Light is no longer capable of striking the ordinary Organs. In the same Manner as when a Person is behind a thick and high Wall, he scarce hears any one that is talking on the other Side.

The
Sight.
Cause of
Twilight.

It must notwithstanding be acknowledged, that one may better hear a Man speaking on the other Side of a Wall, than be lighted by a Flambeau placed behind the same Wall. There are two Reasons for this Difference.

First, the Motion of Light is intercepted and extinguished much more easily than that of Sound. A single Piece of Paper is capable of veiling Light, and even of extinguishing it. But a Man between four Stone-walls can make his Voice be heard at a considerable Distance; because Sound surmounts the greatest Resistances, puts in Motion the most solid Bodies, and of Course forces its Impression beyond those Bodies: If I hear the Voice of a Man from behind a Wall, the Sound of it is communicated to me partly thro' that very Wall; a Resource that luminous Vibrations are totally deprived of.

Secondly,

The
Light.

Secondly, the sole Communication which Sound has here in common with Light, is above the Wall. Its Beams expanded in the Air above the Wall, light me, very feebly indeed, but still they afford me some Light: Direct Vibrations would, no doubt, light me compleatly. In like manner I should more distinctly hear the Sound of a Voice, if it came directly to my Ears. But it is sufficient for me to see a little of the Light, which passes above the Wall, to conclude, that there are in luminous Matter Vibrations, and collateral Undulations, resembling those in the Air subservient to the Production of Sound. These lateral Vibrations are in a lesser Degree, and the direct on the contrary more lively, which is an Effect of the Subtlety of this Matter so superior to that of Air. If you strike upon a Piece of Timber, every Part of it will shake almost equally. But if one beats the Water in a Lake, the Vibrations will not be so universal; in Air, they are still less; and in Light less still, than in all other Fluids: because the more subtile a Fluid is, the less connected are its Parts, and the more independent of one another; and consequently their direct Motions may be made with so much the less Communication between the collateral Parts, and of Course with so much the greater Velocity. It is for this Reason, that the Propagation of Light is by several Degrees quicker than that of Sound.

Vibra-
tions in lu-
minous
Matter, and
collateral
Undula-
tions.

Why
Light is
propaga-
ted with
greater
Velocity
than Sound

When

When I say that the Motion of Light in the ^{LIGHT.} Sun's Absence, or the Absence of any other luminous Body, is not of sufficient Efficacy to make us sensible of any Properties it is endued with by agitating our Organs, I mean the ordinary Organs. For there are Eyes, in regard of which there is no Night, or at least no Darkness, properly so called.

The Owl sees in the Night *, inasmuch as the ^{Why} Ball of its Eye is susceptible of an extreme Dilation, ^{Owls see by Night.} by means of which its Eye collects a great Quantity of this feeble Light, which great Quantity is a Supplement for its Defect in Point of Force. Perhaps too this Animal is furnished with an Organ of Vision some Degrees finer than ours. *Briggs* knew a Man, who was not a Jot behind the Owl, being able to read in the Dark. The Cat also is reckoned a Rival of the ^{And Cats.} Owl in this Particular, as well as the Mole in its subterraneous Achievements. It is pretended also, that Men in certain Fits of Drunkenness, and Accessions of a Fever, or when choleric, will read in the Dark.

There was a young Woman at *Parma*, who ^{The young Woman of Parma.} could see as clearly at Midnight when all the Windows were shut, as if it had been Noon-day. *Mr. Boyle*, in his Dissertation touching ^{Strange Story related by Mr. Boyle.} final Causes, &c. makes mention of a Gentleman confined in a Dungeon absolutely dark, who, having been there some Weeks without seeing

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* Observat. Physiq. Tom. II. p. 198.

The
SIGHT.

seeing any thing, imagined at last that he discerned a little Glimmering; which Glimmering increased daily, so that he could now see his Bed, and Objects of the like Bulk. At length he could see even the Rats that came for his Crums, and mark their Motions very distinctly.

It is certain that a Place must be exceedingly dark indeed, where a Person who has remained there any long Time cannot plainly discern Objects. This is observable every Day in a dark Chamber. The principal Reason assignable for our Inability of seeing in the dark, is the great Light our Eyes are accustomed to. This Organ is, as it were, worn out with it, in the same Sense as we say Tiplers have lost their Taste. We have seen how the Boy brought up in a Forest, and accustomed to weak Odours, had his Smell in as much Perfection, or rather more exquisitely, than Hounds. I imagine, that any one used to Darkness would likewise have a Delicacy and Sharpness of Sight sufficient to produce a distinct Perception of Objects. It

Defect of the Organ, the Cause why we do not always see. is therefore the Defect alone of our Organ, if we do not see at all Times. For we are incessantly surrounded with Light, and with Light that is more or less ever in motion. This Truth is farther proved by an Instance in the

Journal des Sçavans of 1677, which here follows Word for Word. A Man having wounded his Eye with a Wire, which he broke in stringing his Lute, after making use for some Days of

Strange
Story in
the *Journal des Sçavans*.

of cooling Remedies, that were prescribed him, in order to preserve his Eye from the Inflammation that threatened it, all on a sudden found he could see clearly enough, in the midst of Darkness, to discern every Object, and to read all Sorts of Characters. This Symptom continued for several Days, or, to speak more properly, several Nights: during which Interval he saw nothing but with his sick Eye, that could not in the mean while bear even the Light of a Candle, much less that of the Sun in the Day-time; so that he was then obliged to keep it shut.

This Man, as is plain, had his Day-Eye, and his Night-Eye, and the Reason of it is evident. The Inflammation of the diseased Eye had rendered it sufficiently sensible of being as much affected by the feeble Images of nocturnal Light as the sound Eye was by those of the Day. So that this latter Species of Image must rather wound this disordered Organ, than enlighten it.

Light being always existent, and diffused thro' the whole Universe, as we have been just observing, the Shocks communicated to it by the Sun, or every other luminous Body, put it into successive Motion in the same manner, as the Vibrations of a sonorous Body agitate the Air to a wide Degree of Circumference. We have specified the Time these Vibrations or Sound takes up in passing thro' a given Space. Light, so subtle as it is, employs also a certain Time

Propaga-
tion of
Light.

The
SIGHT.

to communicate itself; but this Time is proportioned to its Subtilty. For Example, it is seven or eight Minutes in arriving to us from the Sun, that is to say, in making thirty Million of Leagues. It is about four Millions of Leagues in a Minute, and almost seven Hundred Thousand Leagues in a Second. What a prodigious Rapidity of Communication, compared to the three Hundred forty-six Yards, which Sound is propagated thro' in a Second, and to the four Leagues and a half, which it makes in a Minute! Light is transmitted almost a Million of Leagues for every single League that Sound is traversing. It is therefore a thousand times more subtile and more rarified than Air that produces Sound.

Error of
some Phi-
losophers.

By admitting this great Superiority of Light one conceives the Possibility of this rapid Propagation. But the Opinion of those who imagine that Light is transmitted to us by the Emanation of the Sun itself, that this Matter actually travels the Space we have been mentioning, that it parts from the Sun, and reaches us in seven Minutes; this Opinion, I say, seems beyond all Probability. A Cannon Bullet, with its utmost Swiftneſs, would take up five and twenty Years in making the like Way. Now such Velocities are as impossible, as the Revolution of all the Firmament in a Day round the Earth.

The Reflexion and Refraction of LIGHT.

THE Propagation of Light, or, if you please, its Motion, is ever in a direct Line. The Way Light is propagated.

This Motion of Light, in a direct Line, changes its Direction when it meets with a smooth Surface, for Instance, that of a Looking-Glass, or when it passes obliquely from one Medium to another, as from Air to Water.

The Change of Direction of the Rays of Light, by falling upon a smooth Surface, is called *Reflexion* of Light; because the Light reflects, or rebounds, from this Surface, as a Ball does from a boarded Floor. Experience has taught us, that Light is reflected from these smooth Surfaces, with the same Force, and the same Inclination, with which it fell upon them: or, in other Words, that the Angle of Incidence EFK of the Ray EF, Fig. 1, Plate III, and its Angle of Reflexion KFI are equal. of Reflexion of Light.

The Change of Direction incident to Light, that passes from one Medium to another, is but a turning of the first strait Line, which turning of Light is termed *Refraction*; because in Effect the Ray thus determined from its first Direction seems to be *broken*.

Tho' it be not Light which really falls upon these Surfaces, or actually passes in these Mediums,

LIGHT. diums, but only the Vibration, that is communicated to the luminous Matter which is already upon these Surfaces, and in these Mediums ; we make no Scruple nevertheless of saying, that Light falls upon a Surface, that it passes in a Medium, inasmuch as these Expressions are more conformable to the common Way of conceiving their Effects. It is sufficient to acquaint the Reader, that we mean no more by these *Falls*, or this *passing* Quality of Light, than the Propagation of luminous Vibrations.

When the Medium, wherein Light enters obliquely, is of greater Density than that in which it was, for Example, when it passes from Air into Water, or from Water into Glass, it is refracted in approaching the Perpendicular drawn in this new Medium, to the Point of its Surface where the Light falls. The Ray EF, that falls in Air upon the Cube of Glass or of Water ABCD, would pierce it according to the Direction FL, if this Cube contained only Air ; but consisting of Glass or Water, the Ray is refracted in approaching the Perpendicular FH according to the Direction FM, if the Cube is of Glass, and according to the Line FN, if the Cube is of Water : because Glass being of a greater Density than Water, refracts the Ray the more, or determines it the more to the Perpendicular FH.

But in case Light passes obliquely in a Medium of greater to one of less Density, it is refracted,

fracted, or turned, on withdrawing itself contrarily to the Perpendicular of the Medium which it pierces. For Instance, when the Ray FM, which has pierced the Cube of Glass ABCD, passes afresh in the Air that is below this Cube, instead of keeping the strait Line FMO, it is refracted from M to P on its Direction from the Perpendicular MR of all the Space OP. LIGHT.

This is what is called the *Refraction* of Light. We are convinced by Experience, how much Light is turned from its direct Way in every Medium. For Example, in passing from Air into Water, it diverges a Fourth of its natural Distance from the Perpendicular; in Glass it diverges almost a third, or six seventeenths. When it quits these dense Mediums to pass in Air, it is as far distant from the Perpendicular, as it had approached it on its Entrance: that is to say, it is refracted a fourth Part on leaving Water, and about a Third when it retires from Glass. So that the Ray EF above the Cube, and the Ray MP below it, both in the Air, are parallel to one another.

The Geometricians express themselves more exactly; tho', perhaps, not with a Clearness necessary for the Generality of our Readers.

I will only speak one Word in regard of those to whom I shall explain these Matters, and of those, who understand them already, that the Geometric Method of accounting for the Refractions of Light, is expressed in the

LIGHT. Plate; where they will find, that the Sine of Incidence EK is to the Sine of Refraction in Water K 3 or H 3, as 4 is to 3, and that this same Sine of Incidence EK, is, to the Sine of Refraction in Glass, K 11 or H 11, as 17 is to 11, and *vice versa* as to the Refractions of the Ray that passes from the Cube into Air.

If the Surface of the Medium into which Light enters is found convex, as is the Lens AB, Fig. 2; then supposing three Rays Parallel GCC, the middle Ray G, falling perpendicularly on the Medium of the Lens, will pierce it without being turned from its first Direction, and will describe from G to T but one strait Line. But the collateral Rays CC, falling upon the lateral and sloping Parts of the Lens, become oblique, in respect of the Perpendiculars of this Spot of the Surface, marked by the two pointed Lines DD: so that they are refracted on their approaching this Perpendicular DD.

These same Rays, on departing from the Lens into Air at the Points dd, pass obliquely from a denser Medium to a Medium of less Density. They must consequently then be broken, on their Determination from the Perpendiculars marked in the Plate. So that they would always be approaching the middle Ray, to which they would unite themselves at last in a single Point S; where they cross one another, and from whence they are separated afresh at T.

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Plat. III.

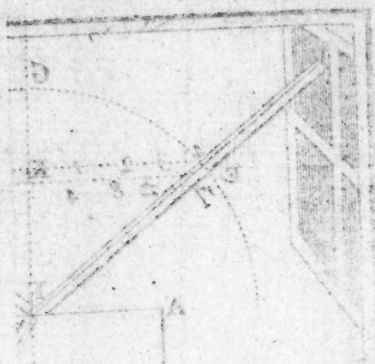


Fig. 1

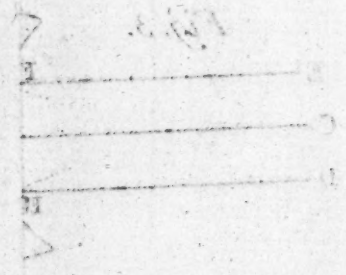
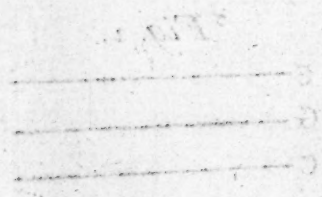


Fig. 1.

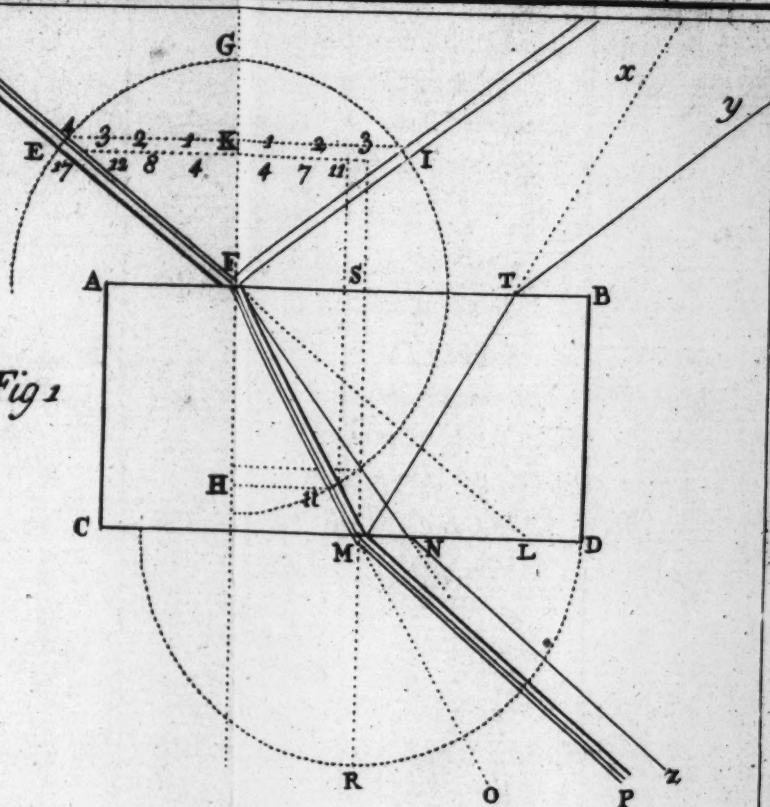


Fig. 2.

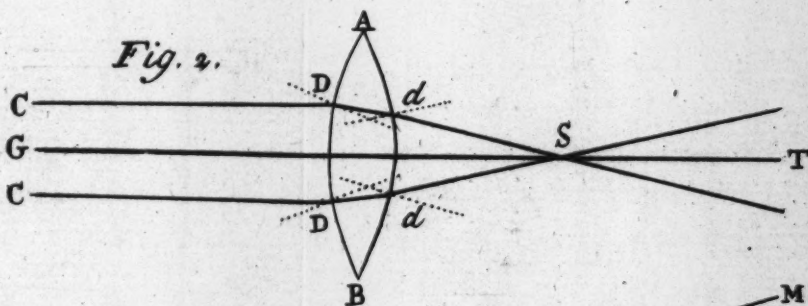
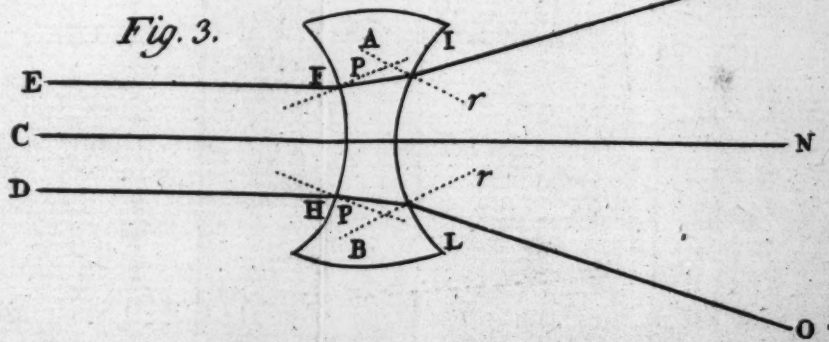


Fig. 3.



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This Point of Re-union, is called the Focus of the ^{LIGHT.} Lens, and these Rays, thus conducted to the ^{Focus of} same Point, are termed *convergent* Rays; but, ^{the Lens.} when they separate themselves again as at T, ^{Conver-} they are stiled *divergent* Rays. ^{gent Rays.} ^{Divergent}

If, on the contrary, the Surface of the Medium, into which Light enters, be concave, either on one Side only, or on both, as in the Lens AB Fig. 3; then the middle Ray C will cross the Lens in a direct Line CN: because this Ray falls perpendicularly both on the concave Surface FH of the Lens, and the convex Surface IL of the Air. But the collateral Rays ED fall obliquely upon one and the other Surface; whence they become subject to the Laws of Refraction.

They enter at the Points FH into this dense Medium. Instead of keeping in a strait Line, they must necessarily be diverged in approaching to their Perpendiculars p, p. They depart from the Lens, or pass into Air of less Density to the Points IL. There, instead of pursuing again a strait Line, they must keep wide of their Perpendicular rr, and go to M and O: consequently, these Rays are twice diverged from the middle Ray, which renders the intire Ray *divergent*, in a contrary Direction to that which passes thro' the convex Lens.

We must observe, that in the one and the other Glass, tho' the Ray in entring makes its Approaches to the Perpendicular, and at its

LIGHT.  darting away is wide of it, it ever continues notwithstanding to approach the middle Ray, as in the convex Glass, or to keep wide of it, as in the concave. And the Reason is, because the Perpendicular of its Entrance, and the Perpendicular of its Exit, from the Glass, are under contrary Directions. So that the Ray in its Approaches to the former, and its keeping clear of the latter, is always curved in the same manner.

SEQUEL of the MOTIONS of LIGHT ; their CAUSES.

New Properties of Light. **S**UCH are the principal Properties of Light known before Sir *Isaac Newton's* Time.

In order to display those, which this great Man and other his learned Contemporaries have added to these, let us have Recourse to the Cube of Crystal, Fig. 1. Plate III.

Reflexion from under the Cube of Crystal.

The Ray EF falls upon the Cube of Crystal at the Point F. A Part of this Ray is reflected from under the Surface of this Cube from F to I ; a Portion of it breaks even at M, as we have intimated ; a Portion of this Ray at the Point M is reflected from under the Surface of Air from M to T, where it is broken from T to Y, instead of going directly to X. Another Portion, which it is impossible to delineate in a Plate, is scattered in the Glass. One Part of this is lost, extinguished in the Crystal ; the other

other is illuminated, and darts away from every ^{LIGHT,} Point. Sir *Isaac* has observed, that this Light, ^{Vibrations} scattered in a Cube of Crystal, is tossed like a ^{of Light} Ball, as it were, between the Surfaces of the ^{in the} Cube, by Thousands of Vibrations, like those we ^{Cube of} have admitted for the Propagation of Light. ^{Crystal.}

In fine, the same Gentleman has remarked, ^{Accelera-} that if a Ray falls perpendicularly upon a Cube ^{tion of the} of Glass, as from K to F, its Motion increases ^{Rays per-} at its Entrance, and is accelerated from F to H, ^{pendicular} far from being retarded by its Rencontre with ^{to the} the Glass, as was the Opinion of the Antients. ^{Crystal.}

The Followers of Sir *Isaac Newton*, in order ^{Causes ac-} to solve these Phenomena, say that each Particle ^{ording to} of Matter is endued with an attractive Quality; ^{the Fol-} that this Quality, tho' immaterial, is notwith- ^{lowers of} standing attached to Matter, and that the more ^{Sir Isaac} a Body consists of material Parts, the stronger is ^{Newton.} the Force of Attraction.

In this System Light is attracted by transpa- ^{BA ONT} rent Bodies in the same Manner as the Load- ^{change} stone attracts Steel-Dust. So that when a Ray, ^{the} as KF, falls perpendicularly on a Cube of Glass, ^{Veritas} which already attracts it, this Attraction of the ¹⁷⁸ Glass, joining itself to the first Motion of Light ¹⁷⁸ that is in the same Direction, so much the more ¹⁷⁸ augments the Motion of this Ray, which en- ¹⁷⁸ ters then the Glass with the greater Velocity.

But if a Ray falls obliquely on a Cube of ¹⁷⁸ Glass, as EF, then the Attraction of the Cube, ¹⁷⁸ which acts perpendicularly to its Surface, does ¹⁷⁸ not

The not at all occur in the same Direction as the
 Slight. Ray, this tending to L, the Attraction exerting
 itself at H. So that the Ray being between
 these two Powers, is forced to take the middle
 Road FM.

Why the This Velocity of the Ray is less in Water,
 Velocity because Water does not contain so much Matter
 of the Ray is less in as Crystal, and therefore has less of Attraction.

Water. The same Effort of Attraction, which broke
 the Ray at its Entrance into the Crystal, breaks
 it still more at its Exit; because this Attraction
 exerts itself on all the Surfaces of the Crystal, to
 push the Ray towards the Surface it is nearest
 to.

Causes of: A Cartesian, to account for these Effects,
 these Ef- has precisely nothing else to do, than to substi-
 fects ac- tute the Word Impulsion for that of Attraction,
 cording to tute the Word Impulsion for that of Attraction,
 the Carte- and to establish it as a Principle, that this Pro-
 fians. perty is produced by the Fluid which surrounds

Two Ad- the Cube of Crystal. He will reap two Advan-
 vantages over the Newtonian Philosophy. The
 over the first is, that his Cause is universally known and
 Newto- truly mechanical; the second, that it explains
 nian Sys- all the Phenomena observed by Sir Isaac, and
 tem. those even which are inexplicable by the Doctrine
 of Attraction. This we are going to see, in
 continuing to observe our Ray fallen in the Cube
 of Crystal, in Fig. 1.

One Part of the Ray FM is reflected from
 the Bottom M of the Cube of Crystal towards
 T in the same Manner, as a Part of the Ray

EF

EF which falls upon this Cube is reflected from LIGHT.
F to J.

The *Newtonian* Philosophers, to explain these two Effects, are necessitated to assert, that these Reflexions result from a Vacuum, in Contradiction to two evident Propositions; to wit, that smooth Surfaces reflect Light, and that a Vacuum is incapable of Reflexion. Recourse of the *Newtonians*.

As a Proof that it is from a Vacuum these Rays are reflected, and that Attraction is the universal Mobile of Rays, they add, that in case we place Water under the Cube, the Reflexion MT is much less, because Water attracts Part of these Rays. If, on the contrary, the Air be pumped from this Cube, and there be produced a Vacuum, the Reflection becomes the more compleat. It is therefore the Vacuum that is under the Cube, and the Attraction of the Cube, which reflect and render more vivid this Portion of Ray. Now if an immaterial Cause reflects a Ray from the inferior Surface of the Crystal, why shall not a Reflexion from the Surface above be consequent to the same Cause? They subjoin to these Reasons the prodigious Inequalities of the smoothest Ice, which they do not look upon at all as endued with a Property of reflecting Light regularly enough for the Formation of Images.

The Reflexion from the lower Surface of the Crystal, on which the *Newtonian* Philosophers build their Foundation, is a Proof that Attraction, New-
tonian At-
traction
the Im-
pulsion of
the Carte-
sians.

LIGHT. tion, which is their general Cause, is nothing else but the very Impulsion of the *Cartesians*.

What At- Attraction is a Force by which one Body is traction is. made to approach another; and its Effect ought to extend itself to, and terminate in, the Center of the attracting Body. But the Ray MTY, reflected from the Cube, is impelled a good way beyond the Body where the Attraction is supposed to be. This Reflexion therefore is not at all produced by any attracting Virtue peculiar to this Body. For such a Property would carry the Ray to the Center of the Glass, and the Cube of Glass would absorb this Ray, as a Sponge sucks up Water which it seems to attract. Wherefore this Reflexion is caused by an Impulsion, that is exterior to this Body, and which surrounds its Surface.

In effect, since we see that a Ray, which falls upon a Glass or upon the Surface of Water, is reflected in Part, why may not the Ray that has pierced this Glass or this Water, and falls upon the Surface of Air, be also reflected from this Surface? If one pumps out the Air, the Reflection becomes the stronger. From whence I conclude, that there remains still under the Crystal, a Matter, which its Subtlety and Motion render more proper to repel Light; and that this Repulsion is not at all the Effect either of a Vacuum, or of Attraction.

The impelling Force of a surrounding Fluid, which under the Crystal is very capable of repelling

* O
† E
Newton

impelling Light towards the Cube of Glass, and ^{Light.} beyond the Cube, will not lose any of this Power on the upper Surface of the Crystal: and it is this impelling Power which we have already assigned as the Cause of Refraction, and of the Velocity of Light.

As to the Reflection of a Ray from the Surface of the Crystal, which the *Newtonian* Philosophy attributes still to a Vacuum; it is evident both to Reason and our Senses, that it results from the very Matter of the Crystal, and not from a Vacuum. ^{Light is reflected by the actual Matter of Bodies.}

The Vacuum is a Space intirely formed for the Reception of Matter, and no Ways capable of resisting it, or of reflecting it. *M. l'Abbe des Fontaines* * and *Bannieres* † have solidly proved its Impotence in this Respect. But I do not know whether what a Gentleman of great Penetration, *Monfieur de Voltaire*, has delivered on this Head in the 140th Page of his *Elements*, is not still a stronger Proof against the *Newtonian* System. “The inherent At- ^{Voltaire's} traction of Matter, says he, is not at all ex- ^{Sentiment.} tended to the whole.—The Mystery of Light reflected from amidst Pores and from Surfaces, without touching those Surfaces, has Depths that are unfathomable by the Laws of Attraction.”

In

* *Observ. sur les Ecrits des Modernes*, Tom. 15 and 18.

† *Examen & Refutation des Elemens de la Philosophie de Newton*, &c.

LIGHT.

In effect, it would be here in vain for those Gentlemen who adhere to Sir *Isaac Newton's* Principles, to call in Attraction to their Aid. This Force, whatever it be, acts perpendicularly to a Cube, and towards this Cube. It cannot therefore repel Light from thence; and, consequently, cannot produce this superior Reflexion, which is in a contrary Direction to its Action. It is neither a Vacuum, nor Attraction, that produces the Reflexion of Rays. This Reflexion therefore proceeds from the actual Matter of the Glass.

Refuta-
tion of the
reflecting
Varnish
substituted
in lieu of
the New-
tonian
Vacuum.

In the mean while some Naturalists, dazzled by that Philosopher's Experiments, and frightened at the same Time by his System of a reflecting Vacuum, have hammered out a third Opinion, a Sort of a Medium between the other two. They agree with the *Newtonian* Party, that Light is not reflected from under Bodies; but they pretend it is from under a Fluid, with which the Body is impregnated; and forms upon this Body a kind of Varnish*. To deliver my own Sentiments, this Bed of Varnish serves only to cover the Vacuum and the Mistake of Sir *Isaac Newton*; for it cannot stand the Test of a Counter-Examination, disappearing on producing the least Proof against it. Nor is the Reflexion of Light assignable to any other Cause, than either to the Pores of Sir *Isaac*, or the Matter of *Des Cartes*, and all real Naturalists.

Monfieur

* Monf. De Mairan, Journal des Sçavans, 1719.

Monfieur *Bannieres*, and ſome others, com-
 poſe this Varniſh with Light itſelf. According
 to them, this kind of Light takes up its Abode
 in the Pores of Bodies, is the Property of each
 Body, and forms for it a Sort of Atmosphere.
 It is red in red Bodies, blue in blue, &c. and a
 Body is not red for any other Reaſon than be-
 cauſe it is full of this red Light; which on
 Account of the Analogy reflects only red Rays,
 and extinguishes others.

LIGHT.
 Opinion of
 Monfieur
Bannieres,
 &c.

But, in my Opinion, this Analogy muſt pre-
 ciſely hinder red Light from reflecting red
 Rays. I ſhould imagine, that theſe two Lights,
 being of the ſame Nature, would be rather united
 and attracted, as Oil is joined to Oil, and ſeems
 to attract it. So that theſe Philoſophers would
 ſeem to me to have a better Foundation, did
 they make this Analogy ſubſervient to a kind of
 Attraction that diſplays itſelf in Refraction, and
 not ſubſervient to Reflexion. Becauſe theſe Ef-
 fects being oppoſite, their Cauſes of Courſe
 ought not to be the ſame.

Refuted.

Again, from whence comes it that a red
 Body is impregnated with red Light, rather
 than that of another Colour? The Reaſon is,
 they will answer, becauſe the Configuration of
 its Pores, or its Texture, is more ſuſceptible of
 receiving red Rays. But if this Body received
 red Rays, the Vibrations of the red Rays exte-
 rior to the Body, would penetrate it, ſink the
 red Rays that already quietly fill the Pores, and

H

would

Light would chase them from these Pores by the same Vibration which they have in a greater Degree than those Rays. In short, a corporeal Texture, proper to absorb or let pass red Rays, will never be endued with a Faculty of stopping and reflecting them: Such a Body therefore will not appear to us red.

If the Texture of a Body does not stop, or reflect, the exterior Rays, it will neither be able to retain the interior, which you suppose agitated by the exterior. And if the interior Rays are not retained by the Texture of a Body, they will be influenced by the external Rays, and unable to repel or reflect them. If, on the contrary, you say that they reflect them, you must allow that these internal Rays are retained in the Texture of the Body, and the Substance of this Body is their fixed Point. Now if the Body be the fixed Point of internal Rays, why may it not also be that of the external?

If therefore you would have the Texture of a red Body constitute the first Principle of its Colour, it is a shorter Way of going to work to say, at once, that it is done by reflecting the red Rays by its proper Substance, without recurring to the contradictory Circumlocution of Pores, which absorb the red Rays, to make them subservient afterwards to the reflecting Rays all of the same Nature. For, in the Supposition of a proportional Agreement, between

the coloured Globules, and the Texture of the Body, there is a mutual Contact. If there be a Contact, there is necessarily a Reflexion of the Globules, which could not be admitted, and an Introduction, Transmission, or Extinction of the others. In this Case then it must be absolutely granted, that these are the Rays reflected from the very Substance of the Body, which convey to our Eyes corporeal Images, together with the Colours, that are peculiar to them.

In short, were it not the Matter itself of Bodies which reflects Light, from whence comes it that the hardest and the smoothest Metals should reflect more Light than porous Substances, and Surfaces rough and uneven? These last Bodies have more Pores, a larger Vacuum, and more Varnish, and consequently more Places to reflect Light from, according to Sir *Isaac Newton*, and his reformed Disciples.

The Difficulty started from the Inequalities of the Surfaces, is not a material Objection. These Surfaces, in respect of the luminous Matter, are only a Texture of Mounds and Hollows. This we are agreed in. The whole of the Light cannot be reflected from thence regularly, that is to say, in the same Direction. We agree farther, and believe this Irregularity to be absolutely necessary for the Perfection of Vision, or the Action of seeing.

To view one's self in a Looking-Glass, it is not at all requisite that all the Rays reflect them-

LIGHT. selves in the same Direction; it is enough that they are reflected sufficiently towards our Eyes to form an Image. When I behold myself in a Glass, a thousand Persons, disposed in different Places, may have a fair View of me at the same Time. Therefore my Image must occur in these thousand Points of Sight. The Glass then reflects the Rays, which it receives from me, in Thousands and Thousands of different Directions.

These Inequalities of Directions proceed both from the Inequality of my own Surface, and the Inequality of the Surface of the Glass. These Inequalities are consequently necessary for the seeing an Object in several Places at once. If a Looking-Glass could be procured polished to such a Degree as to be void of any manner of Inequality, and able to reflect all the Rays in the same Direction, there would be but one Line of Direction, and the Image reflected could only be seen in this single Line; or rather nothing would be seen, because this Reflexion of Light would be too strong and lively. The same Inconvenience would happen, were Light reflected from beneath the Surface of Bodies without touching them, that is to say, by the Vacuum, or the luminous Varnish; inasmuch as neither this Vacuum or Varnish have seemingly any Inequalities.

Smooth Bodies differ then from others, not because they have no Inequalities, but by reason they have

have fewer. These Inequalities are Mountains very close to one another. They reflect Light from all Parts; but their Tops being almost contiguous, and at the same Time very smooth, the Portion of Light which they reflect is exceeding lively, because it is considerable, and the Reflexion of it regular and uniform.

Thus when you make the Sun dart upon a Looking-Glass, the Flashes that rebound from it at an equal Angle, are only produced by the Rays reflected by the Summit of the Inequalities or Risings of the Glass, to which perhaps are joined some Rays from the Bottom of the Hollows. All the Remainder of the Light, or of the Images, which this Glass diffuses around, results from reflected Rays, and perchance reflected more than once, on the Sides of these Risings.

These two kinds of Reflexions are observed in all smooth Surfaces. For Instance, in a Picture in Oil-Colours, the Point of the direct Reflexion is termed a *false Light*; because this great Reflexion hurts the Sight, and is an Impediment to our distinguishing the indirect Reflexion, which presents in a softer manner the Image of the Object: The first Reflexion is uniform, the second has infinite Varieties.

False
Light of a
Picture.

The bounding about of Light absorbed and scattered in the Cube of Crystal, and the Vibrations in Proportion to which arises this extraordinary Agitation, are moreover Phenomena

Light agitated by
Vibrations
among the
Surfaces of
the Prism,
and scattered
a-
that round.

LIGHT. that are inexplicable by Attraction, and to account for which, Recourse must be had to Impulsion. It is this Light, absorbed by the Speculum, and by Prisms *, and scattered around, which forms the Penumbra, or Shade, that surrounds and confuses the Image which passes thro' these Glasses; and it is in order to extricate the Image from this Confusion, and to render it more distinct, that Diaphragms † are applied to the Glasses of Telescopes, and black Paper is wrapped round Prisms, when we make Experiments.

These Phenomena proceed from two Causes, viz. the Reflection of Light in the solid Substance of the Crystal, and the *refrangent Reflection*, that is to say, the Reflection produced by the Fluid that surrounds the Crystal.

Refringent Reflection. Whatever numerous and strait Pores may be supposed in the Crystal, the Reflexion, which Light suffers on the Surface of Glass, is a Demonstration that it strikes against its Matter in passing through it, and that it suffers also from the Reflexions in the Inside of its Substance. This is sufficient, in Conjunction with the Diversity of small reflecting Surfaces, to scatter a Part of these Rays in the Crystal. One Portion of these scattered Rays will remain absorbed and extinguished in the Crystal, another will fly off from

* A Prism is a solid triangular Glass.

† A Diaphragm here is a Ring of Paper.

from every Part of it, and Occasion the confu-
sed Light I have been mentioning.

By supposing an Impulse, round a Cube of Glass, ^{Cause of the Reverberation of Light.} capable of repelling Light, that can have but one determinate Force, and one certain Direction, we easily comprehend, that among the Rays which have passed through the Crystal, whether directly, or after scattering themselves in it, and which have a natural Tendency to darting from it, we may easily suppose, I say, that there is an Infinity of them too feeble to get the better of the surrounding Impulse. In that Case this Force repels these Rays, diffuses them afresh in the Crystal, and dispatches them to another Surface, which they will pass thro', if their Direction is not so oblique, but that by it they will be a second Time repelled, in case their Force be inferior to that which surrounds them. It is the Reason likewise why these Surfaces repel reciprocally the wandering Rays, and scatter them partly in the Crystal, partly in the neighbouring Air. Such is the Cause of the singular Reverberation of this Light.

The Fluid which receives these Impressions of Light, and returns those reciprocal Impulsions, is elastic. These alternative Sallies of Light must consequently be produced by Accession and by Vibrations, as Sir *Isaac Newton* has observed. Besides, all our Philosophers

LIGHT. hold, that Light consists in the Vibrations of
 Light con- luminous Matter, as Sound is formed by the
 sists in Vi- Vibration of the Air. So that Sir *Isaac's* Obser-
 brations of vation serves only to give ocular Demonstration
 luminous of the most generally received System.
 Matter.

The great *Newton* was sensible of all these
 Consequences. He has acknowledged in all
 this the Insufficiency of his Attraction. He
 Insuffici- had made Preparations for Experiments in Refer-
 ency of Attraction ence to this Subject, which he had not Time
 to execute. Those which he accomplished gave
 him an Occasion of forming a Train of Ideas
 and Conjectures; where one finds already a
Subtile, Æthereal, Matter, which fills the *Hea-
 vens*, and the *Vacuum* of the Air-Pump, and
 whose Density, Elasticity, and Vibrations being
 greatest at the Circumference, but less towards
 the Center of the celestial Spheres, impel, urge,
 and press Bodies towards this Center, and, in
 short, produce that famous *Gravitation*, which
 is no longer an immaterial Attraction, and the
 celebrated *Reflection* of Light, which results no
 more from under the Vacuum. It is very
 perceptible by these Expressions, that a longer
 Life, and a greater Number of Experiments,
 would have rendered Sir *Isaac Newton* a com-
 pleat *Cartesian*. He searched sincerely after
 Truth, which would infallibly have conducted
 him to Impulsion, and its Mechanism.

The Mechanism of IMPULSION substituted in the Room of ATTRACTION, in order to explain all the preceding Phenomena.

WE have hitherto substituted Impulsion for Attraction ; but Impulsion is a bare Term. Shall we then incur the Censure so justly imputed to the *Newtonian* Sect ? It is an incontestable Point, that the *Impulsion of a surrounding Fluid* extends itself a great deal better than an *Attraction* that is *immaterial* and *inherent in Matter*. But this *better* is still no ways satisfactory to a true Philosopher. He requires Mechanism. He knows very well that a Body is incapable of being moved without being impelled by some other, and, consequently, that all Motion is caused by Impulsion ; but he would fain be acquainted with what particular Kind of Impulsion. We have hitherto talked of the Impulsion of a surrounding Fluid. It is an easy Matter to conceive that all Bodies are encompassed with a Fluid. But one does not discern, at first Sight, how this surrounding Fluid can, in certain Cases, impel a small Body towards one of greater Bulk : It is this Mechanism I am going to explain.

A solid Body differs from a Fluid, inasmuch as the former is composed of Parts that have an intimate mutual Contact in certain Points, and keep one another reciprocally in a State of Inaction.

Mechanism of Impulsion

Light. Inaction. A Fluid consists of small Parts, which, on the contrary, are disunited among themselves, and in continual Motion. This Motion, which constitutes a Fluid, I call an *Intestine Motion*. He whose Imagination would be determined by the Senses, will form a gross Image, tho' natural enough, of intestine Motion, from that of Atoms which one sees fluttering up and down in a Ray of the Sun, when it penetrates singly into a Room somewhat darkened : This Motion is in every possible Direction.

Intestine
Motion,
what.

A like Motion being supposed in Fluids, it must be allowed, that the Bodies they surround are of Course acted upon, in all the Points in Contact with them, by an infinite Number of little Impressions, resulting from their agitated Particles. These Impressions constitute the Principle on which Fluids act, and the Basis of the Mechanism of almost all Physical Phenomena.

Force, in general. Force, in general, is the Product of the Quantity of Matter, and its Velocity, or the Square of its Velocity. So that all the active Force of a Fluid depends on the Quantity of its intestine Motion, the Number of agitated Particles, and their Quantities. But without Motion all other Modifications are of no manner of Efficacy. Gun-powder acquires no Force, but in Proportion to the Motion that is communicated to its Principles by Fire.

Ethereal

Ethereal Matter, in which all Bodies float, is ^{LIGHT.} furnished with all the Requisites to make ^{Ethereal} a powerful Fluid, viz. subtil, numerous, Matter. solid, and briskly agitated Particles. I call, in this Place, by the general Name of Ethereal Matter, all the Species of Matter of greater Subtilty than Air, whatever may be their Number and Diversity. These Principles, thus far, are but little different from those even of Sir *Isaac Newton*; but I mean the *Newton*, forming reasonable Conjectures on the Causes of Effects, *Newton*, the real Naturalist, and not a Man confined to mere Observations, mere Calculations.

The Ethereal Matter, I have been speaking of, penetrates the Pores of Bodies in some measure as Light penetrates Glass. Now Light, notwithstanding this Facility, ever strikes upon the glassy Surface, as is demonstrated, by simple Reflexion. It meets again with a like Impression against the internal Particles of Glass, when it pierces it; and it is owing to this Impression, that it is partly absorbed and extinguished in the glassy Substance, and that of other Bodies; that is to say, that one Part of Light is there deprived of its Motion. In like manner, altho' Ethereal Matter enters without any Obstruction the Pores of all Bodies, it suffers nevertheless some Kind of Shock against all the Particles of Matter of which a Body is composed.

One

LIGHT.

One may draw several important Consequences from these Principles; but I am obliged to confine myself in this Place to some of the most considerable.

Ethereal Matter meets with Shocks in corporeal Substances. Therefore in that Case it must necessarily abate a little of its Motion, and of course a small Matter of its Force. The Particles of this Fluid in Contact with the Surface of the Body, undergo the same Impressions, the same Diminutions of Motion and of Force. This Portion of Fluidity consequently has less of Action and Energy, than the Particles that are at a greater Distance from the Body. Therefore the Ethereal Matter that surrounds the Body, not in Contact with it, has more of Action and more Force, than that which penetrates it, and holds it in an immediate Contact. On which Account, Matter placed between these immediate Particles and those that are more exterior, and which will receive their Shocks, will be under a Necessity of giving way to the more powerful Impressions of the exterior Particles, and will be impelled by them towards the Body, where the Action of the Fluid is in a less Degree. So that this agitated Matter will appear attracted by the Body, altho' in reality it be impelled by the Fluid that surrounds it.

This

This Impulsion will act parallel to the Perpendicular of the Surfaces: for they are the Surfaces themselves of the Body, which prevent the Resistance found towards the Body, and which constitutes the attractive and preparatory Principle of Impulsion. The exterior Columns of Air, where the impulsive Force resides, are likewise parallel to these Surfaces. The Impulsion therefore is itself parallel to the Surfaces, and equal in all the Points that are at an equal Distance from the Surfaces. Therefore a Body entirely subjected to such an Impulse, will be in an Equilibrium amidst the Forces that surround it, according to the Parallel of the Surfaces. It will of course be conducted by their Impulse, without inclining either to one or other of these Forces situated in the plain Parallel to the Surfaces: Consequently this Body will be impelled perpendicularly to these Surfaces.

When a Ray of Light falls on the Surface of a Crystal, it is found placed in the Column of the Ethereal Fluid, that is in immediate Contact with the Crystal, and has the least Force of any, as we have seen. This Ray therefore is found freed from all the superior Force of the exterior Columns of the same Ethereal Fluid, to whose Impulse it must of Consequence more or less give way, towards the Perpendicular whither this Impulse tends, and accelerated if it follows this Direction.

It

LIGHT. It is by means of this Mechanism, that Light, which seems attracted by the Glass to which it is exposed, is actually impelled by the Fluid which surrounds this Glass *. It is by this Impulse, that this same Light is there refracted, or turned from its Road, when it passes it obliquely, as we have seen. It has also been observed, that the Refraction is by no means made in the Substance of the Glass, but that the Ray is broke before its Entrance into this Substance †; that is to say, at the Approach of the Surface, or in the first Column of the Fluid which surrounds it. In effect, were Light refracted in the glassy Substance, it would describe a Curve; because this Refraction being in that Case made successively by all the Parts of this Substance which it traverses, there would be a Necessity for each of those successive Parts to imprint on the Ray its small particular Refraction: which in the whole would cause the Ray to make a Series of infinitely small Refractions, or a Train of infinitely small Angles, and, consequently, a Curve. Whereas in the Supposition that Refraction is made in the first Column of the Ethereal Fluid that is in Contact with the Surface of the Crystal, we must conclude, that from the Entrance of the Ray into the Pores of the Crystal, after its Refraction, it follows in a direct Line,

Refraction
before the
Ray enters
into the
Glass.

* M. de *Voltaire*, Lib. Citat. p. 107.

† Ibid. p. 101.

Line, the Determination given it in this first Light.
Column.

But why does Glass absorb Light rather than any other Matter? It is because Glass has Pores precisely formed for the Admission of Light; and that the kind of Ethereal Matter which more abundantly penetrates Crystal and other transparent Bodies, is also that which is more proportioned for its Rencontre with luminous Matter.

All Bodies in general have their attractive Force, inasmuch as they are all penetrated with Ethereal Matter, and surrounded with a powerful Fluid. If I present a Curtain Rod, a Stick, a Straw, to a dripping of Water falling perpendicularly, this Water will determine itself to the Body I present to it, and will glide all along this Body at a considerable Distance from the Perpendicular.

The other Phenomena of powerful Attraction, as that of the Diamond, Amber, Sealing-Wax, &c. are accounted for by the same Mechanism, and by the Proportion we assigned for the Refraction of Light. All the Differences, in regard of these Attractions, consist in the Diversity of Pores, of the Kinds of Ethereal Matter, and of the Kinds of attractive, or rather impulsive Matter, which is looked upon as attractive. What Body is there that is not now found to be electrical, or attractive? Friction and Shocks are the Means of rendering a Body electrical;

LIGHT. trical ; because a greater Degree of Motion is thereby communicated to it, and consequently more Force to the Fluid which penetrates and surrounds it.

In short, this Impulse of the Columns of the Ethereal Fluid surrounding solid Bodies, is not only the Cause of Refraction, but also that of all the Phenomena attributed to Sir *Isaac Newton's* Attraction. The very Gravity of Bodies, the Ebbing and Flowing of the Sea, the famous Gravitation of Sir *Isaac*, are so many Effects dependent on the general Principle I have been lightly touching on.

Cause of
Refraction
and all the
Phenomena of
Attraction

The second important Consequence I draw from the Shocks of Ethereal Matter against corporeal Substances, is, that the Effects resulting from it are in a direct Ratio of the Quantity ; that is to say, these Effects are proportioned to the Bulk of Bodies, like those of Sir *Isaac Newton's* Attraction. For Instance, Water loaded with Salt, breaks Light more than a very thin limpid Water. A Crystal, or a Diamond, causes a greater Refraction of Light than the most ponderous Water ; because this Crystal is a greater deal heavier, or contains a much larger Quantity of Matter, than a like Body of Water. This is the Mechanism of the most considerable Refraction.

As all the Pores of Bodies are supplied with Ethereal Matter, there is not a single Particle of a corporeal Substance that is not in Contact with

with this Matter. The Effect that will result ^{LIGHT.} from this Contact, will therefore be proportioned to the Quantity of these Particles. The Quantity of these Particles, is what constitutes the Gravity of a Body. Consequently this Effect will be proportioned to the Gravity of Bodies.

So that the Impulse, or Motion, a Body will receive by the Action of the Ethereal Fluid, will be so much the more considerable, the more Substance that Body will contain, and the greater shall be its Gravity. It is in this Proportion, that the Action of this Fluid produces the Gravity of Bodies.

In like manner, the Shocks of an interior Fluid against a corporeal Substance, where it resides, will weaken the Action of this Fluid against this Body, in Proportion as the Number of these Shocks shall be more or less considerable. These Shocks are proportioned to the Quantity of the Substance. The Diminution of the Force of the interior Fluid will be therefore proportioned likewise to the Quantity. But the Superiority of the exterior Force of the Ethereal Fluid, is by so much the greater, as the interior Fluid is weaker, or has more of an attractive Disposition. Consequently, this Impulse, which surrounds Bodies, is still proportioned to this Gravity.

By

LIGHT.

Impulsion
no Ways
inferior to
Attraction

By this means Impulsion acquires all the Advantages of *Newtonian* Attraction; and the terrible Objection of that Philosopher vanishes, who pretends to demonstrate, that an Impulse cannot act, but in relation to the Surfaces; whilst all the Phenomena, for which he has invented Attraction, display themselves relatively to the respective Bulks. This is what he has tacked to his Attraction inherent in all the Particles of Matter. But it is evident, that Impulse has the same Advantages, without incurring the Absurdities of Attraction. It has, besides, this additional Excellence, that it accounts for a greater Number of Phenomena.

The general Rule we have just established for the Attraction of Light, proportioned to the Gravity of Bodies, supposes that the Particles which compose the Weight of Bodies, are of the same Nature. But, if this Weight should be found consisting of Particles proper to embarrass the Motion of the Ethereal Matter comprehended in the Body, then this Matter, being more relaxed and weakened, would occasion a greater Superiority of the exterior Columns, and consequently a stronger Impulse. This Body therefore might, with a less Gravity, be endued with as great, or a greater, Degree of Attraction, than another of more Gravity. Now this is actually the Case, as to Matter composed of Particles in Motion, as Fluids are

are, because these Motions produce more powerful and more frequent Shocks against the Ethereal Matter, which penetrates these kinds of Bodies. For Example, Water, tho' of less Gravity by a great deal than Crystal, refracts Light but a little less than that does. Consequently, Water, in regard of its Density, refracts Rays more than they are refracted by Crystal.

Among Fluids, those which are furnished with a good deal of Oil, Sulphur, and volatile Particles, are capable still of a stronger Refraction; inasmuch as the Ethereal Matter is more compact, more embarrassed by the Parts of Sulphur, and more powerfully agitated by the volatile Particles with which this sulphurous Matter is penetrated. It is the Reason why Spirit of Wine produces a Refraction as strong again as that which results from Water, tho' the Density of Water be far more considerable.

Were there solid Bodies composed of Parts as different from one another, as those are which constitute Water and Spirit of Wine, we should find, in respect of them, the same Difference of Refraction. For Instance, Amber, of much less Density than Crystal, refracts more strongly than Crystal, in regard to its Density; because Amber consists likewise of a Composition of Parts proper to cause an additional Embarrassment to the Ethereal Matter which penetrates it.

LIGHT.

Another peculiar Property of impulsive Attraction, which I shall also endeavour to explain, is, that this Attraction is increased not only in Proportion to the Gravity of Bodies, but still farther, *proportionably to the Minuteness of them*. A small Piece of Crystal attracts Light more forcibly than a larger : The Reason of it is this.

The Attraction on the Anvil is produced by an Impulse of the Ethereal Fluid, which surrounds corporeal Surfaces. This impulsive Force will be therefore proportioned to these Surfaces. Now the Proportion of Surfaces is greater in small Bodies, or, what is the same Thing, small Bodies have more Surfaces in regard to their Bulk, than great ones have in respect to theirs. The exterior Columns then of the Ethereal Fluid, where the impulsive Force resides, will have a greater Extension, more Points of Contact, and, consequently, more Influence over small Bodies, than over large ones. Therefore the pretended Attraction of these small Bodies must necessarily be stronger, than that of the large ; as Sir *Isaac Newton* has also observed, without being able to account for it.

This new Ratio of Surfaces does not at all destroy that of the Bulk of Bodies, which we have been establishing. That of Surfaces is derived directly from the Quantity of the Impulse, which surrounds the Body, or from the intrinsic

Value

Value of this Impulse. The Ratio of the LIGHT, Bulk of Bodies, is taken indirectly from the Impulse; but directly from the Weakness of the Fluid, that is within the Body; by reason of which Weakness, the Force of the surrounding Impulse increases respectively, altho' its intrinsic Value be ever the same.

COLOURS.

COLOURS are either Modifications, or The Nature of actual Parts of Light. They are *Modifications* of Light according to the *Cartesians*, according to *Des Cartes*, who hold, that the Diversity of Colours depends on the manner of Light's being reflected by corporeal Substances. They are *Parts* of Light, according to the Doctrine of Sir *Isaac Newton*; According to Sir *Isaac Newton*, who imagines that Light, or white, is a Composition of seven Sorts of Rays, viz. red, orange, yellow, green, blue, indigo, and violet: and that these Rays, or Globules, the Principles of the seven Original Colours, are unalterable. So that, according to him, each Colour is inseparably attached to each of these Species of Rays. And a Body is stiled red, when it reflects red Rays or Globules, and when it absorbs, or extinguishes, others. It is called blue, when it solely reflects blue Rays, or at least blue Rays in greater Number than all the rest; and so of other Colours. In short, a Body appears white, when it reflects all the seven

Colours.  Kinds of Rays at once. If, on the contrary, a Body absorbs and extinguishes almost all the Rays, it is termed black; if it gives free Admission to the greatest Part of the Rays, it receives the Appellation of transparent: if it permits none to enter it, without extinguishing one Part, and reflecting the other, it is named an opaque Body.

We have seen how Rays are reflected from under a Body; how they pass thro' it; how they are there refracted. The Extinction of Rays is a Compound of all these Effects. A Ray is extinguished in a Body, when it penetrates it so as to be refracted in several different Directions, in the heterogeneous Substances that compose all opaque Bodies; to be reflected in the hollow Pores of these Bodies, and there at last to lose its Motion. A Ray passes across a Body, when this Body is so thin, that it is not of sufficient Substance to stop it in its Pores, there to refract, reflect, and extinguish it. Such is I singlass, thin Horn, &c. A Body, tho' of Density, is nevertheless transparent, when it has Pores every way disposed for the Passage of Light. Of this Nature is Water, Crystal, &c.

Cause of
the Colour
of Bodies.

Sir *Isaac Newton* says, that a red Body is that which reflects red Rays. In the mean while a red Glass appears such, not only at the Point of Reflection; but likewise in its transparent Parts, and even colours the Objects with

with red, that are behind it. We ought then to say, that red Glass extinguishes all other kinds of Rays, and that it reflects, and allows a Passage only to, red Rays.

Colours.

But, according to this Principle, if I put two Glasses together, one blue and the other yellow, I ought not to find behind them any Colour at all. For the blue Glass, which I suppose before, will have extinguished all the Rays, except the blue; and the yellow Glass behind will in its Turn extinguish the blue, So that there will not be a single Ray behind, and, consequently, all will be black. I am taught nevertheless by Experience, that these two Glasses thus joined, reflect on their back Part a green Colour, composed of two others, blue and yellow. Consequently, these Glasses do not extinguish every kind of Ray, that is not of their own Colour. Whence we see, that this System, tho' very satisfactory and almost universally received, is not however without its Difficulties.

Therefore, when we talk of a red Ray, we do not mean that this Ray is actually coloured with red; but only, that this kind of Globule is made in a manner proper to excite in our Eyes the Sensation of a red Colour. In a Word, this Ray is not red, but the Agent or Cause of the Sensation of Red.

The Followers of Sir *Isaac Newton*, if we may believe them, tell us, that this Sentiment is

Colours.

not a System, but a natural History of Colours : wherein Sir *Isaac*'s Imagination has had no other Part, than the Invention of Experiments proper to demonstrate these Properties of Light : That he has no where asserted, that Light or a white Ray was composed of the Principles, or seven primitive unalterable Colours ; that when he had divided by the Prism a Ray into seven Colours, and having put each of these Rays to the same Proof, he was convinced, that these primitive Rays were indivisible, unalterable, and, consequently, the Principles of Light and of all Colours : In the same manner as Anatomists regard the simple Fibre as the Element of all the Parts of our Composition ; because this Fibre is the ultimate Term of their Dissections.

The Instrument Sir *Isaac Newton* made Use of to dissect Light is the Prism ; and the different Refrangibility of Rays is a Sort of cellular Texture, or Interstice, which conducted him to distinguish each of these Species of Rays.

Experiments of
Sir *Isaac*
Newton on
Light.

Let a Ray of the Sun enter a dark Room ; receive it upon a Prism. It will refract, and give you at the lower End of the Room an oblong Image, P. T. fig. 1, Pl. IV. made up of seven Rings of Colours of great Beauty ; to wit, (beginning from below) a red Ring, an orange-coloured, a yellow, a green, a blue, an indigo, and a violet.

In the mean while the Ray of the Sun you receive upon the Prism is a white gilt. And if
you

Fig. 1.

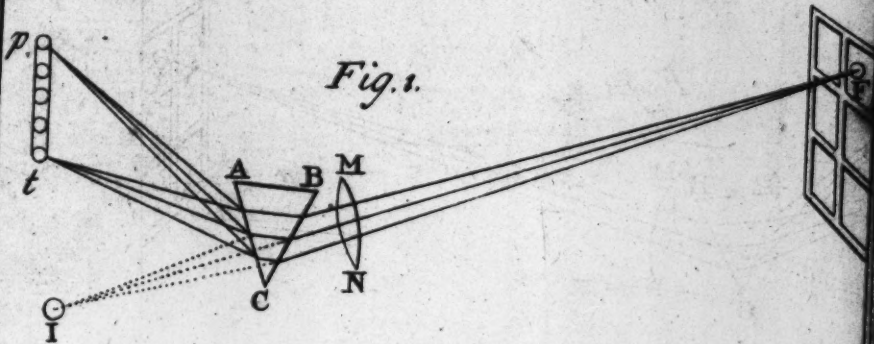


Fig. 2.

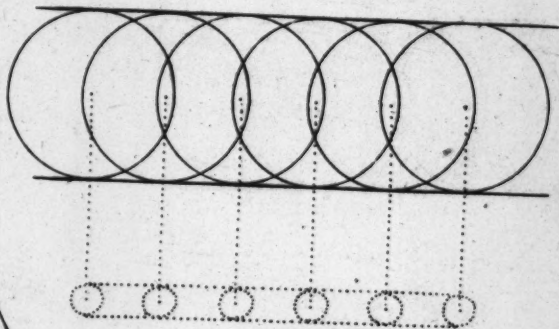


Fig. 3.

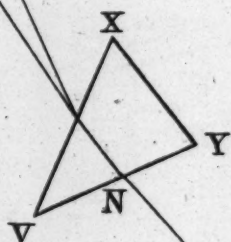


Fig. 4.

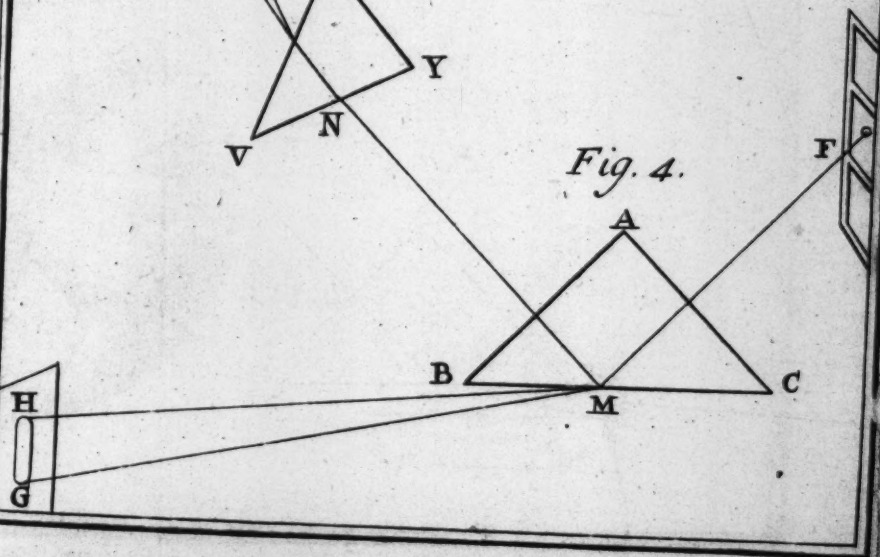




Fig. 1.

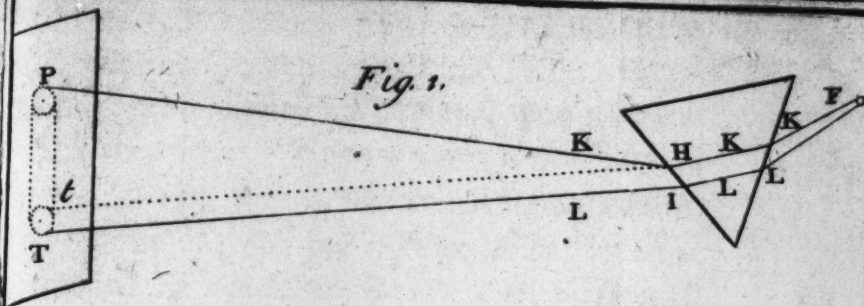


Fig. 2.

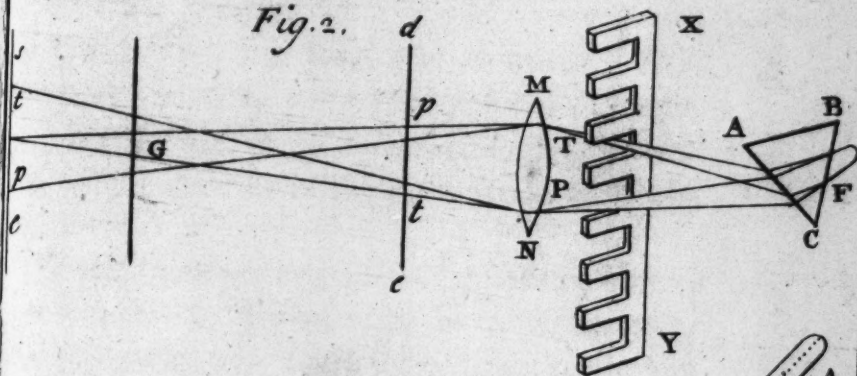


Fig. 3.

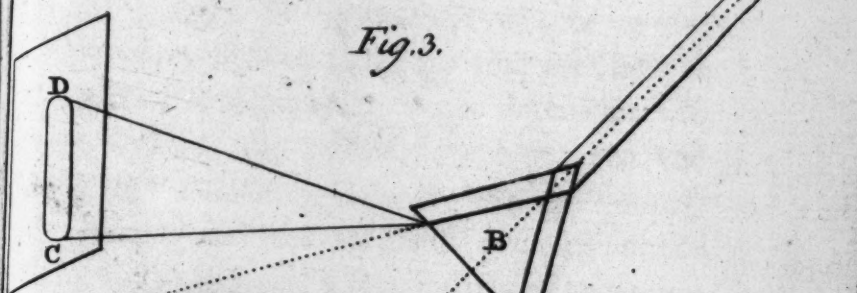
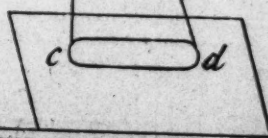


Fig. 4





you receive it a second Time on its Exit, from the Prism and intirely against the Prism, that is to say, previously to its Division, you will find it still very white. Even when it is divided into seven Colours, if you receive it upon a Lens, M, N, fig. 2, and put a Piece of Paper to the Focus G of the Lens, in order to receive all these Rays centered in a single one, you will farther discover this Ray to be altogether white. In *d, e*, and *s, e*, you have the seven Colours; but in *s, e*, they are in a reversed Order, by reason of the Increase of the Rays produced by the Lens.

If you intercept any one of the seven Colours, whether in X, Y, here, or in *d, e*, there, of the Lens with the Teeth of a large Comb X, Y, or any other Body, the white or intire Ray G will cease to be white, and will be of the Colour composed of the Rays that are suffered to pass. For Example, if one intercepts the violet Colour, the purple, the blue, and the green, the remaining Colours, *viz.* the yellow, the orange, and the red, will produce in the Focus G of the Lens, a Ray intirely of an orange Colour. If the red and the violet are intercepted, the whole Ray G will become a sort of green. When these intercepted Rays are permitted to pass, the white is immediately re-established. Light or the white Ray is therefore an Assemblage or Collection of the seven coloured.

Colours, coloured Rays, blended together in a just Proportion.

If the Comb X, Y, be gently passed before these Colours, one distinguishes successively all the Changes of the Colours, that are thus combined. If you pass it hastily, there appears only white; in the same manner as live Charcoal, when swung around, exhibits but a Circle of Light; because all the Impressions are made almost at once. The Sensation of Whiteness is therefore the Assemblage likewise of the seven primitive Impressions. In short, Sir *Isaac Newton*, to leave no stone unturned in order to demonstrate this Truth, has copied Nature herself, in composing a white Powder with original Colours mixed in a certain Proportion.

The first Experiment of this Philosopher*, by which a Ray is divided with the Prism into seven Colours, is by no means a new one, tho' it is the Basis of his grand Work: but those, who made it before him, were not apprized of its Consequences, acquiescing in this single Experiment, which he multiplied and varied in a thousand and a thousand different Shapes during the Space of thirty Years.

One ought to observe attentively, that, according to the Rules of Optics, the Ray, which is refracted in the Prism, and tends to form the coloured Image P, T, must not paint this Image agreeably to its actual Height. The two
Rays

* It is the third Experiment of his Book.

Rays H, I, which quit the Prism, are parallel, Colours.
 are equally inclined to the Surface of the Prism,
 and have the same Perpendicular. Therefore
 they are subjected to an equal Refraction on
 passing from the glass Medium to Air; and,
 consequently, must continue to be parallel quite
 to the Image P, T, and of course reduced in
 the Space, T, t.

All that I have said would be a necessary
 Consequence, were Light a simple Substance,
 whose Parts were all of the same Nature, and
 subjected to the same Laws of Refraction, as
 was the established Opinion before Sir *Isaac*
Newton. But the Experiment of the Prism, all
 simple as it is, is a Demonstration, that there
 are no other than original Rays, to wit, red,
 orange coloured, &c. which follow these known
 Laws, and that all other Rays are subject to a
 greater Refraction, or are more refrangible;
 because they are more feeble, and give way
 more to the Impulse we have been speaking of.
 This Experiment concerning Reflection, proves
 then, that Light is made up of different Kinds
 of Rays differently refrangible.

Another Experiment, simpler indeed, which
 I made accidentally, and which since I have
 met with elsewhere, seems to point out more
 evidently the same Truth.

Thro' a Hole A, Fig. 3. Pl. IV. sufficiently
 large, made in the Window-Shutter of a Room,
 dark, or not dark, let pass a Ray of the Sun
 in

Colours. in order to receive it on the Angle of the Prism B, in such a manner, that this Angle divides the Ray into two equal Parts. Each Moiety of this Ray, falling upon the opposite Surfaces will produce a coloured Image C D, c d, every red Ray of which C, c, will be situated on the Side of the Axis ABF of the intire Ray, or towards the Perpendicular; whilst the other Colours will be at a Distance, so that the violet Colour will be at D, d; and that, because the red Rays of each Moiety of the intire Ray, having more Force, yields in a less Degree to the surrounding Impulse, and passes in a directer Line, and, consequently, nearer the Perpendicular, and the Axis of the total Ray.

But the seven Rays rendered by the Prism, are they actually the unalterable Principles of Light and Colours? Are they not divisible into a greater Number? Cannot one make them less compounded? For Example, green, is it not compounded of blue and yellow?

The Answer to these Queries is supplied by new Experiments.

Make a very small round Hole F, Fig. 1, Pl. V. thro' the Window-Shutter of a dark Room. Ten or twelve Feet from this Hole receive a Ray upon a Lens MN, with ten or twelve Feet of Focus. Receive this refracted Ray upon Paper I, placed at the Focus of the Lens. Immediately next to the Lens put a Prism ABC, which refracts the Light in p t; and you will have

have in this Image your seven primitive Colours ^{Colour.} in as many Circles, separated very distinct from one another.

Receive this Image on a black Pasteboard pierced on purpose to let pass each of these Circles of original Rays. Refract a new each of these Rays behind the Pasteboard; and receive this fresh Refraction upon a white Pasteboard placed two or three Feet from the Prism. You will find that this Circle changes neither its Figure, nor its Colour; that it is capable of no farther Divisibility, but is absolutely unalterable, how numerous soever the Refractions may be to which you expose it. It is unchangeable both in regard of Figure and Colour, because each of these Circles consists of Rays of the same Nature, of the same Colour, of the same Refractivity, and which constantly preserve the perfect Parallelism ascribed to universal Light before Sir Isaac Newton's Time.

Push still farther the Proof of these simple Rays. Instead of receiving them upon a white Pasteboard, receive them upon coloured Glasses. You will find them pass across these Glasses without the least Alteration of their Colours: that is to say, a blue Ray, which shall pass thro' a red Glass, will still be blue behind this Glass; a red Ray will still be red behind a yellow Glass, and so of the rest: because these Rays being simple and immutable, these Glasses must either totally extinguish them, or let them pass such

Colours. such as they are. Now these solar and primitive Rays have too much Vigour and Vivacity to become extinct in a Glass.

He should therefore have thus dissected Light even to its ultimate Rays, to come at its simple and unchangeable Parts.

But is not the green Ray or Circle composed of blue and yellow Rays? No. For first, in order to a Mixture of this kind, the yellow Circle and the blue Circle ought to join and be confounded with the green. Now these three Circles are distinct and separated. Secondly, form two Images of coloured Circles in the same Room. Let the yellow Ray of one of the Images, and the blue Ray of the other, pass a-cross a Pastedboard. With Prisms placed behind these Pastedboards make both these Rays fall upon the same Point, and they will produce no more than a green Circle. Observe this compounded green Circle a-cross a Prism, which appears oblong; while the simple green Circle of the seven Circles, seen across the Prism, seems exactly round. The Reason why the green Circle, composed of a blue and of a yellow one, appears oblong, is, because it is not simple, but formed of two Rays that have different Degrees of Refrangibility. The green Circle of the coloured Image seems perfectly round, because it consists of simple Rays, Rays that are original. Thirdly, the green Circle of the coloured Image is not composed of a Portion

of

of blue Rays, and a Portion of yellow, is so evident, that if in the Passage of the Rays of the Prism you intercept either a blue Ray, or a yellow, or both the Rays together, as we have seen Fig. 2. of Plate IV. the green Circle exists in all Respects the same. It has therefore nothing of these collateral Rays, and is of Course a simple and an original Ray.

Conceive then that a Ray of the Sun, or of circular Light is an Assemblage of coloured Circles confused together. Suppose for a Moment that this circular Ray is a Collection of seven Counters placed one upon another, the first of which is red, the second orange-coloured, the third yellow, the fourth green, the fifth blue, the sixth of an indigo Colour, and the seventh of a violet. Now, in making this Collection of coloured Rays pass by the Prism of the first Experiment, it is just as if you threw your Parcel of Counters on a Table in order to tell them, or shew them separately, partly, at least, as in Fig. 2, Pl. V. when each of the Colours will be very distinct.

But in this first Experiment your coloured Counters are large, and not sufficiently extended. They advance besides a little one upon another, and become confused at their Extremities. These Extremities therefore form Mixtures and a Composition of Colours.

In

Colours.

In the last Experiment, Fig. 1. Pl. V. the Diameter of the Counters is diminished by the Smallness of the Ray, and the same Extension is preserved along the whole Row of these Counters, whose Centers are equally distant from one another, as in Fig. 3. because the Refraction is the same. So that the seven coloured Counters are no more in Contact, but separated and detached one from the other. Each Counter and the Colour it displays is perfectly single and uncompounded, as in Fig. 3, and Fig. 1.

Doubts
concern-
ing the
*Newto-
nian Sy-
stem.*

All I have been saying in relation to Colours, is the pure Doctrine of Sir *Isaac Newton*; and I leave it to him to warrant his own Experiments. For I aver, that, how exact soever I have been in the Execution of his Processes, I could never separate the seven Circles of Colours of his eleventh Experiment, in the manner they are expressed in the first Figure of Plate V. It was notwithstanding what I particularly wished to succeed in, because I looked upon it as the fundamental Experiment of the *Newtonian* System. In order to accomplish this Point, after having several Times repeated the Experiment and still failed in it, I had the Presumption to aim at improving on even Sir *Isaac* himself. According to the Principle adopted by this Philosopher, said I to myself, to make a regular Division of the seven Colours, there is no Difficulty;

culty; but to receive a very strait Ray on a Colours Prism, that will refract and scatter this Ray to a great Degree, according to the Length of the coloured Image. Now a Prism with concave Surfaces, ought to give the seven coloured Counters at a considerable Distance from each other: For it is the Property of concave Glasses to scatter the Rays. I therefore procured a Prism to be made with concave Surfaces, and several others with different Angles, all solid, and of the finest Glass of the famous Manufacture of *St. Gobin* in *Picardy*. They were formed under the Inspection of *Monf. Bernieres*, a Gentleman well versed in natural Philosophy, and my particular Friend. All this Apparatus did not by a great deal answer my Hopes. The Separation of the seven coloured Circles has still remained with me the grand Work.

I have seen since, that the most celebrated Professors of *Sir Isaac Newton's* Principles, such as *Monf. de Voltaire*, and Naturalists the most dextrous at his Experiments, such as the *Abbe Nolet*: Neither the one nor the other of them was happier in this Respect than myself. I was not insensible besides, that *Monf. Mariotte* too, so well acquainted with Experiments, had by no means succeeded in the Separation of the seven *Newtonian* Colours; but had refuted, by other Experiments, the System of the *English* Philosopher relating to coloured and unalterable

K Rays *.

Colours.

Rays *. *Monf. Dufay*, the late Loss of whom the Republic of Letters exceedingly regrets, who so closely applied himself to Experiments on Light, did not at all seem successful in this particular one. For in adopting the *Newtonian* primitive Colours, he has reduced them to three, red, yellow, and blue, of which he compounds the other four; which is a Demonstration that he made no distinct Separation of the seven coloured Circles.

But there were two Circumstances that effectually discouraged me in my Enterprize. First, the Principle on which *Sir Isaac Newton* founded his Experiment, is demonstratively false in Fact. This Principle is, that a very strait Ray, refracted by the Prism, gives a coloured Image, as long and as extended, as that given by a large Ray; and that the Centers of coloured Circles remain at the same Distance in both Cases †. Now it is evident, on the contrary, from the Experiment I have made a hundred Times, that the straiter a Ray is, that is to say, the smaller the Hole is, that is made in the Window-Shutter of a darkened Chamber, the smaller likewise and shorter is the coloured Image, and the more the Centers of the Circles approach one another. The Confusion therefore of the Circles ought to be the same in all the kinds of large and strait Rays. Secondly, even the

* *Journal des Scavans* 1681.

† See Fig. 2, 3, Plate V.

the Figure by which Sir *Isaac Newton* expresses this Experiment, gives rise to Suspitions. He every where reckons seven primitive Colours, and in this Figure he exhibits only five Circles: Are all these Things regular in a Man that actually saw the seven Colours in seven distinct Circles? Could the great *Newton* give us a Conjecture for an Experiment, he who was so reserved in regard of Conjectures? Thirty Years Exercise in a dark Chamber ought to have rendered him more dextrous at these Experiments than any body else; especially, as he was abundantly supplied with Instruments, and all other Requisites for the carrying them on.

His Principle is what embarrasses me the most. But tho' in Rigour he be contradicted by Experience, and a narrow Ray forms a short Image, perhaps this Image is still more extended, in relation to its Ray, than is the Image of a broad Ray; by which means the coloured Circles of a small Image become a little more distinct, at least, than those of the large one. Indeed one cannot be too reserved, when the Case tends to the Condemnation of so extraordinary a Man as Sir *Isaac Newton*, in what he has given in the finest and most convincing manner. His Experiment is real, if it has succeeded but once. I wish that some great Masters in Experimental Philosophy, such as the Abbé *Nolet*, would set themselves about resolving this grand

Colours.

Problem. It would give me no small Pleasure to bear Witness of any one Instance of Success; after which I should look upon the System of Colours to be fixed even to a Demonstration.

Altho' the Circumstances I have been relating, suggest some doubt, whether the Number of primitive Colours be precisely seven, they do no manner of Injury to the System of primitive and unalterable Colours in general. One may admit them without counting them, and that even in less Number than seven, as *Monf. Dufay* has done.

But there is farther a Sect of Naturalists, that are neither of one or the other of these Parties, but imagine, with *Descartes*, that Colours are the Modifications of a Matter perfectly equal, and intirely uniform, and that the Colours of the Prism are only Illusions of Refraction. These last are not aware, that it is demonstrated by the Prism, that Light is composed of Rays differently refrangible. Perhaps they may alledge, that the scattering of a Ray that produces a coloured Image, happens purely, inasmuch as the upper side K, K, K, of the Ray which falls obliquely on the Prism, Fig. 1. Plate IV. and departs from the same, is nearer the Surface of the Prism, than the lower Side L, L, L; and that by this Situation the upper Side is more exposed to the Attraction of this Surface, and to the Refraction it produces: and that therefore this upper Side, K, K, K, being

being more refracted than the lower L, L, L, ^{Colours.}
 the total Ray ought to become divergent, and
 to be lengthened in the Figure observable in the
 coloured Image, tho' all the Parts of it are
 equally refrangible. But let us return to the
Newtonian System.

We saw above, that, according to the *Eng- Sir Isaac*
lish Philosopher, the seven primitive Rays are ^{*Newton*} holds, that
 unequally refrangible; and that it is this unequal the most
 Refrangibility which dissects them, and ranges refrangi-
 each in its proper Class, and Circle of the same ble Rays
 Nature, from red, which is the least refrangible, are also
 to the violet-coloured, which is the most sus- the most
 ceptible of Refraction. *Sir Isaac Newton* pre- reflexible.
 tends, that the Rays which are the most
 adapted for being refracted, are likewise the fit-
 test for Reflection: that the violet-coloured
 Ray, for Example, which is the most refran-
 gible of all the Rays, is also the most reflexible.
 Here is the Foundation of this Opinion. Re-
 ceive the Ray F, Fig. 4, Plate V. upon a
 Prism, the Angle of which A is a right Angle,
 and the Angles B, C, half so. Let this Ray
 fall obliquely on the Prism, in order to have the
 coloured Image in H, G, as in the first Expe-
 riment. Turn the Prism in the Order of the
 Letters, A, B, C, to make the Angle B of the
 Rays M, H, approach the more. When this
 Angle shall be inclined upon these Rays to a
 certain Degree, you will find that from the
 Point M there will be made a Reflection M, N,

Colours.

which we above called a *refringent Reflection*. Receive this Ray reflected M, N, with the Prism V, X, Y, and you will have a new Refraction, t, p, coloured as H, G. Turn slowly the first Prism A, B, C, in the Direction A, B, C, and you will find all the Colours of the Image H, G, pass to the Image t, p, and will observe, that the violet-colour of the Image t, p, will be the first Colour that is strengthened by the Passage of the Rays of the Image H, G, afterwards the indigo, then the blue, and the red will be the last strengthened by this Transmigration of the Ray. Therefore, concludes Sir *Isaac Newton*, the violet Colour is the first reflected, and the red the last. Consequently, the most refrangible Rays are also the most reflexible.

Reasons against Sir *Isaac Newton's* Opinion, that the Reflexibility of Rays is in an inverse Ratio of their Refrangibility.

These Consequences suppose, that this *refringent Reflection* of the lower Surface of the Crystal, and the Reflection from a solid and polished Body are absolutely the same; which Sir *Isaac Newton* was perswaded of, because it is always from a Vacuum, according to him, that Rays reflect. But, these two kinds of Reflections being somewhat different, the Laws of *refringent Reflection* did not seem to me to be justly applicable to simple Reflexion.

From the Experiment we have been surveying, Colours depart not from the Prism A, B, C, to go to H, G, but inasmuch as the lower Surface of this Instrument, from whence these Colours

Colours escape, is not strongly inclined upon these Tracts of Light. For, if this Surface be strongly inclined upon these Rays, those will be found pumped back as it were by the Prism, and are reflected across its Substance ; because, in this Situation of the Prism, the Rays, which depart from the inferior Surface, striking too obliquely the Surface of the surrounding Fluid, have not Force sufficient to conquer the Impulsion, and escape from the Circumference of the Prism. This Impulsion therefore being victorious, pushes back the Rays towards the Prism, and makes the refringent Reflection. Colours.

So at the Time when all the Colours depart freely from the inferior Surface of the Prism, if you gently incline this Surface of the Prism upon these Rays, to make them absorb and reflect these Colours one after another, the violet is the first absorbed and reflected, and red is the last. The Reason of it is evident.

The violet Ray H borders nearest on the absorbent Surface, B, C. This Ray is likewise the most refrangible, or that which most gives way to the surrounding Impulse ; a double Reason why it ought to be the first that is conquered and carried off by this Impulse. The red Ray G, on the contrary, is the most remote from the absorbent Surface. It is the strongest of all the Rays, or that which yields the least to this surrounding Force. It is therefore evident, that, on giving to this Force by

Colours.

little and little, the Superiority over the Rays which pierce it ; the first Rays it ought to stop and carry off by a refringent Reflection, must be the violet, then the purple or indigo, &c. and the last must be the red.

But there is no drawing any Conclusion from this refringent Reflection in Favour of Reflection in general. All the World knows that when a Ball is pushed upon a Surface, from whence it rebounds, the greater the Force of this Ball is, the more it is reflected. Now, according to Sir *Isaac Newton* himself, the red Ray is in the Case of the Ball pushed with the greatest Force ; therefore, *ceteris paribus*, it ought to reflect more vigorously than the rest. So that for the same Reason, that the red Ray is the less refrangible, it ought to be the more reflexible. For it is only the less refrangible, inasmuch as it prevails more than the rest over the Power of Attraction, or over the surrounding Fluid. Now, the greater the Velocity is with which a Ball pierces a penetrable Surface, the more considerable is the Force with which it rebounds from an impenetrable Surface. Consequently, the less refrangible Rays must necessarily be the more reflexible.

S H A D E.

SHADE.

HOWEVER brilliant Light and Colours are, they would not form a single Image, but an immense and uniform Lake, proper rather to dazzle than to enlighten us, without *Shade* to divide, to distribute, to modify them, and in short, to give them all the Force we know they are endued with in regard of the Images they compose. *Shade* is a Diminution of Light and Colours, the last Degree of which is *black*, not inasmuch as the Blackness of a Body is a total Privation of Light, because the Body would be then invisible, but a black is of all Bodies that which reflects the least Light, as it absorbs and almost intirely extinguishes it. A perfect black, or the total Privation of Light, is not properly speaking a Thing visible, because it transmits nothing to the Organ, and is only distinguished by the illumined Bodies that surround it: It is a Sort of Hole or Vacuum in the Body of Light.

The Art of Drawing is a good Proof that the sole Gradation of Shade, and its Distributions and Mixtures with simple Light, are sufficient to form the Images of all Objects, in the same manner as the mingling of Sulphurs, Earth, and Water with Salts, constitutes the Diversity of Savours. It is the same thing, as to the intermixing of every Colour, in the Art of Painting,

Colours, Painting, of which Shade is ever the Ground-Work ; and these Arts we all know only mimick the Operations of Light and Shade, in respect of the Phenomena of Vision.

The ORGAN and MECHANISM of VISION.

The Eye is at once an optical Instrument, and an Organ of Sensation.

THE Eye is not only the Organ which receives the Impression of Images, it is also an optical Instrument, which furnishes these Images with the Conditions requisite to a perfect Sensation. This double Function is distributed to different Parts of this Organ. The whole Body of the Eye is a Sort of Spying-Glass of infinite Perfection, which transmits Images in an exact and compleat manner even to the Bottom of it. This Bottom is invested with Textures of Nerves, on which the Image is imprinted, and by that means the Sensation is produced, of which one of these Textures is the immediate Organ.

In order to give a clear Idea of the Structure of the Eye, and the Mechanism of Vision, let us make Use of the Instance of the dark Chamber, which the Eye in some Measure resembles.

The dark Chamber, its Use.

Shut up a Room so close as to deprive it entirely of Light. Then make a Hole in one of the Window-Shutters, and over against this Hole, at the Distance of several Feet, place a Cloth, or some white Pasteboard ; and you will find, with Astonishment, that all the Objects from without

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Fig. 1.

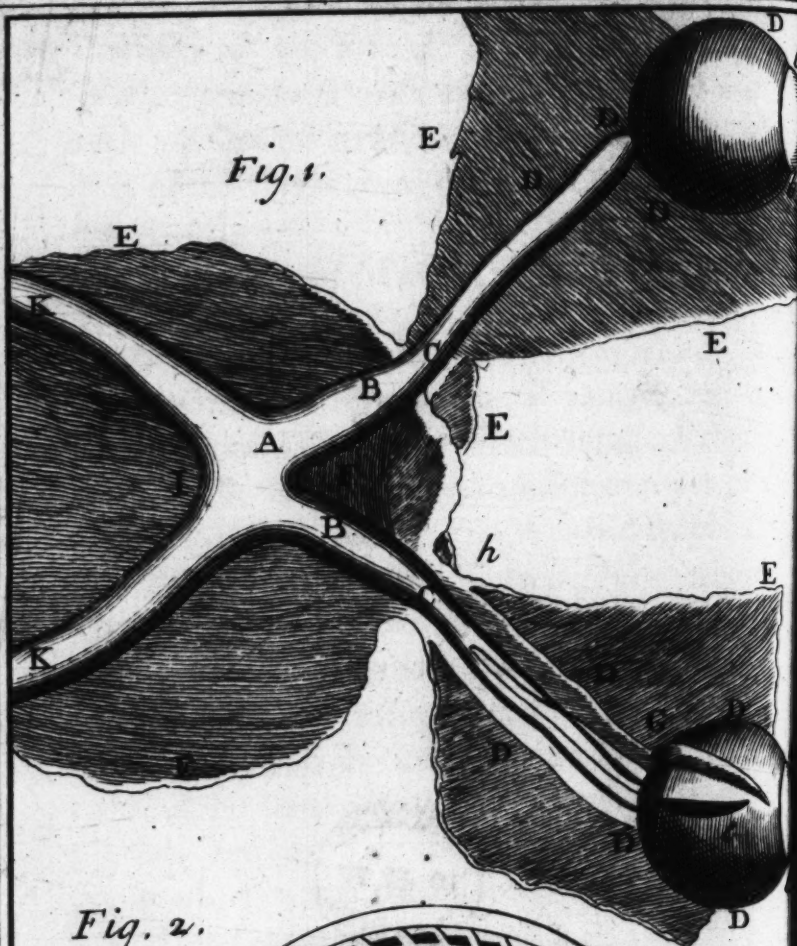
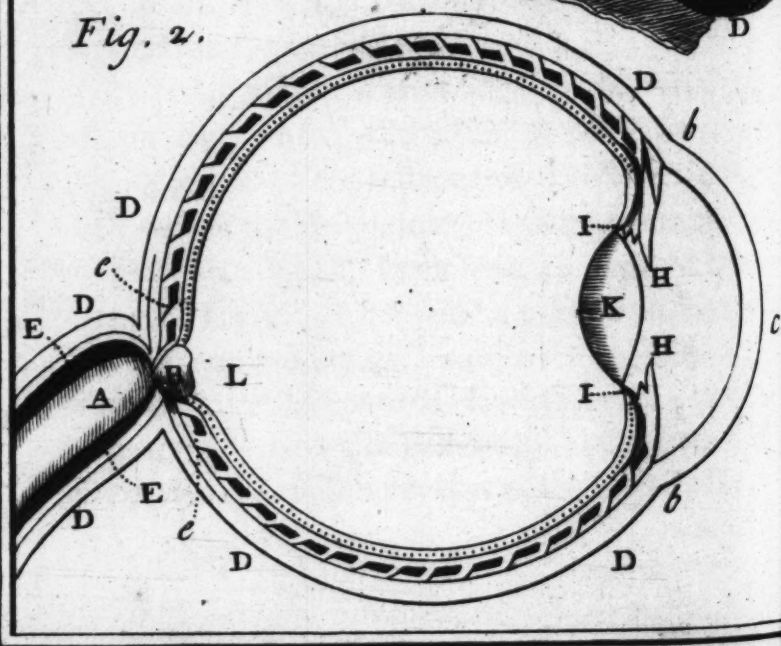


Fig. 2.



without, will be painted on this Pafteboard in the moft lively and moft natural Colours, tho' abfolutely reverfed. For Example, fhould the Figure of a Man prefent itfelf, it will appear with the Heels upwards. If we have a Mind to exhibit thefe Images ftill with greater Life and Exactnefs, let a Microfcope be applied to the Hole of the Window, or a Lens, which, in collecting the Rays, forms an Image more compact and diftinct.

You may make the fame Experiments with only a Box darkened within, with a Tube and a Lens placed at its Entrance; and you will have here the additional Advantage of being able to reprefent thefe Images in a ftate of Transparency, by clofing the hind Part of the Box, where the Image is to fall, with an oiled Paper, or a Pane of unpolifhed Glafs, or by placing in the Box a floping Mirrour, which will reflect the Image againft the top Part of it, where you have fixed your Glafs. All that is wanting in Regard of this Box, to render it, as to fimple Optics, an artificial Eye, is the Figure of a Globe, and having the Lens placed within this Globe.

In the natural Eye the Cafe is formed by fupple Membranes, and the Lens by transparent Bodies and Humours equally transparent.

The Brain and the Nerves are compofed, ^{The Structure and Formation of the Eye.} firft, of a foft Subftance fomewhat refembling new Cheefe; fecondly, of two Teguments of a competent Solidity, called the *dura*, and *pia Mater*,

The *Mater*, each of which is manifestly double.
 E x E. These three Substances form all the Nerves.
 The *dura Mater* constitutes the exterior Coat,
 the *pia Mater* the interior, and the medullary
 Substance occupies the Center.

The optic Nerves. The principle Nerves of the Eye, termed
 the Optic Nerves A B, Fig. 1. Pl. VI. make their
 Exit from the Cranium, one on each Side,
 with all this Apparatus. In the first Place they
 draw their Origin from those Parts of the me-
 dullary Centre of the Brain, which we stile the
Beds of the optic Nerves; see Pl. II.

Then the two Nerves K K tend towards the
 fore Part of the Head, approaching again one
 towards the other; and unite as it were in a sin-
 gle Nerve A, without any Crossing or Confu-
 sion. They afterwards separate one from the
 other, still inclosed in the *pia Mater*, and in-
 vested with the anterior Lobes of the Brain;
 and, after about seven Lines of Way from their
 Separation, they each of them enter into a
 bony Hollow, that leads to the *Orbit*, the Re-
 ceptacle furnished by the Brain for the Eye.
 There they receive from the *dura Mater* the
 Sheath common to all the Nerves. This Sheath
 confines the Nerve, and hinders it from grow-
 ing too bulky and unfizable. This bony En-
 trance forms a Canal of about two Lines; after
 which the *dura Mater* is divided into two *La-
 mine*, one sufficiently thin h E which lines the
 Orbit, the other thicker D D which continues

to serve as a Sheath to the Nerve. From the Angle h, formed by the Division of these two Laminæ, arise the Muscles of the Eye.

The Coat of the *dura Mater* D D, that accompanies the optic Nerve, and concurs to its Formation, is continued in the Center of the Orbit, amidst the Muscles, about the Space of fifteen Lines, (see Plate II. and VI.) after which it expands and swells itself into a Globe, much in the manner as melted Glass is blown into a Bottle.

At the Root of this Expansion, between the Nerve and the Globe, the *dura Mater* forms a circular Band, by means of which it strongly compresses the Extremity of the Nerve, and makes a Sort of Valve, which seems to separate the Globe from the Nerve. This Band pretty much resembles the Paper Ring applied to Telescopes. It is formed like the Valves of the Intestines, by a returning Fold of this Coat; and it is evident, that this Fold was inevitable at the Angle, which the *dura Mater* is obliged to make in order to expand itself all at once into a Globe *. The *dura Mater* D D, Fig. 2. on thus expanding itself, forms the first, or exterior, Membrane D b c of the Globe of the Eye, called the *Cornea*. The anterior Portion b c b of this Cornea is transparent, and corresponds with the Pupil. All the rest is opaque.

The
Eye.

The o-
paque
Cornea, or
Sclerotis.

Tho'

* See Fig. 1 and 2. Pl. VI.

The
E Y E.

The trans-
parent
Cornea.

Tho' the *transparent Cornea* be a Continuation of the *Sclerotis*, or *opaque Cornea* D, D, D, it makes notwithstanding a Part of the smaller Sphere, which seems there added in the manner Crystals are to Watches. By this means it projects a little beyond the common Sphere of the Eye; which Circumstance renders it very well adapted to its collecting a greater Quantity of Rays and Images, in regard of Objects that present themselves sideways to the Eyes.

The *pia Mater* E, Fig. 2. the second Tegument of the Brain and optic Nerve, situated under the *dura Mater* D, expands itself in a Globe like the *dura Mater*, in order to form the internal Membranes, or to double the Cornea. It makes also before its Expansion, a Valve, or circular Band, which strongly compresses the Extremity of the Nerve: but it is divided into two Laminæ, one genuine and solid, that is applied exactly to the inner Surface of the Cornea D, where it is actually complicated and united to the other. I am the first, I imagine, that discovered this Membrane, who demonstrated to the Academy of Sciences its Continuation with the *pia Mater*, and the very distinct Extension of it, even almost to the transparent Cornea.

The Cho-
roides.

The second Lamina of the *pia Mater*, marked by long Points in the Figure, constitutes what is called the *Choroides*, or *Uvea*: but this Lamina, properly speaking, is only a Texture

ture of Nerves and Blood-Vessels, that make their Exit from the inner Surface of the true Lamina I have been speaking of. The
E Y E.

These Vessels convey a Liquid that communicates a black or brown Colour to this second Lamina. Part of these Vessels and these Nerves open themselves on the internal Surface of this Lamina; and there form by that means a downy or mamillary Texture loaded with the black Liquid these Vessels are charged with. *Ruisch* has made a particular Coat of this Lamina, called the second Coat of the Choroides.

This, according to us, would be the third Coat distributed by the *pia Mater* to the Eye; to wit, one truly membranous, united to the Sclerotis, one vascular, termed the Choroides, and one downy, stiled *Tunica Ruischii*.

Towards the fore Part of the Eye the Cho-The Iris. roides is doubled: and this exterior Complication forms what is named the *Iris* H H, in the middle of which is the Perforation of the Pupil. This Iris is furnished with muscular Fibres in the Form of Rays and Circles, by means of which the Pupil dilates and contracts itself. It dilates itself in the Shade and paralytic State of the optic Nerves, by the Repose or sinking of its Fibres, and is contracted when affected by Light, particularly a strong one, thro' the Swelling of its Fibres, into which this strong Light determines the Spirits.

The

The
ORGAN.

The Co-
rona Cili-
aris.

The Cryf-
talline Hu-
mour.

The inner Complication of the Choroides forms on the hind Part the *Corona Ciliaris* H H, in the Center of which is enchafed the Lens of the Eye, called the *Cryſtalline Humour*. The *Corona Ciliaris* or *Ciliary Proceſſes*, on a cloſe Examination, are the laſt nervous and vaſcular Tufts, or Fringes, which expand themſelves on the inner Surface of the Choroides; where they form the ſecond Coat and the *Corpus Mamillare*, the principal Organ of Senſation. They are plaited at this End like the Wriſtband of a Shirt; inaſmuch as, from a grand Circumference they were extended to before, they are reduced to a very ſmall Circle that ſurrounds the *Cryſtalline Humour*. Theſe Fringes, as they are floating, ſurpaſs a little the Bounds of the exterior Lamina of which the Iris is a Continuation.

This external Lamina is complicated * under the Ciliary Fibres, where it grows whitish and thick. It ſeems, in this Termination, to affect approaching to an ungulous Nature, as much as can be expected from its Delicacy; which, indeed, is the Fate of almoſt all Textures formed by the Parallel, and cloſe and compact Beds of nervous Fringes.

Chambers
of the Eye.

The whole Space of the Eye, that is before the *Corona Ciliaris* II, and the *Cryſtalline Humour*

* I have ſeparated diſtinctly the *Corona Ciliaris* from this exterior Lamina.

mour K, is filled with a limpid Water, called ^{The} *aqueous Humour*, in the Center of which ^{E Y E.} swims the Iris H, H, or *Pupil*. So that the Iris divides this Space into two small Chambers, ^{The aqueous Humour.} one before, that is terminated by the transparent Cornea, or exterior Glass of the Eye, b c b, and the other on the back Part a very small one bounded by the Corona Ciliaris, I I, the CrySTALLINE Humour, K, or the Lens of the Eye, and the Iris, H H.

Next to these two Chambers, behind the Co-^{The vitreous Hu-} rona Ciliaris, I I, and the CrySTALLINE Humour K, the Globe of the Eye forms a Space a great deal larger K L, than the preceding ones. This Space is all occupied by a Sort of transparent Jelly, called the *vitreous Humour*. The CrySTALLINE Humour K is lodged in the anterior Surface of this Jelly, as the Diamond is set in a Ring.

The medullary and inner Part A, Fig. 2, ^{The Reti-} of the optic Nerve is expanded as well as the na. preceding Coats, and forms a flabby Texture marked by small Points in the Plate. This Texture constitutes the inmost Membrane of the Globe of the Eye, named the *Retina*, and terminates at the Corona Ciliaris I I. This soft Substance of the Nerve, at the Beginning of its Expansion, forms the small medullary Button B.

The extremely fine Textures that divide the Cavity of the Eye, and make Cells for the

L

Hu-

The Humours it is filled with, are the same which
 E X R. in the Cavity of the Nerve divide and support
 the medullary Substance therein existing.

Such is the Structure of the Eye discovered
 by Anatomy. But the Lights derived from
 Reason and analogous Assistances, let us a great
 way farther into the Nature of this wonderful
 Organ.

A more
 particular
 Detail of
 the Me-
 chanism,
 Forma-
 tion, and
 Uses of
 the Parts
 of the Eye.

It has been evident all along, that every In-
 dividual Sensation is produced by nervous Pa-
 pillæ; and that the Fluid which animates
 these Papillæ, receives by the Glands the Pre-
 parations and Mixtures that fit it for receiving
 the Sensations peculiar to each Organ. It is well
 known that these Glands and nervous Papillæ
 are often one and the same Organ; and that
 they sometimes even add to the preceding Func-
 tions the Filtration of a sensible Liquid. This
 Structure is particularly remarkable in the glan-
 dulous Papillæ of the Tongue, that are at once
 the Organs of the Sensation of Taste, and the
 Receptacles where the sensitive Fluid receives
 its Character, its Mixture, and the Reservoirs
 of a filtrated Liquid necessary to this Sensation.
 The Eye, all wonderful as it is, is nothing else
 than a glandulous Papilla, of larger Size and
 Expansion, and hollower than the other Glands.
 It is like them a triple Organ of Sensation, of
 Preparation of the sensitive Fluid, and of Fil-
 tration. The closest Examination imaginable
 of this nervous Papilla does not make it
 in

in the least degenerate. On the contrary, it reflects a considerable Lustre on the Structure and Use of these Papillæ, the universal Organs of Sensation. This Structure and these Uses, that have been hitherto a kind of Mystery and a System, cease almost to be so in the Organ of the Sight. It is a History of the glandulous Papillæ, even ocularly demonstrated.

A glandulous Papilla is a Tuft and End of a Nerve, destined to the Filtration of some Liquid. The Eye is very evidently the Extremity of the optic Nerve, expanded, and blown, as it were, into a hollow Button full of Fluids. One may trace with one's Eye the Vessels conveying these Fluids, which, from the expanded Coats of the *dura* and *pia Mater* where they are interwoven, open themselves on the Inside of this Organ. The Size alone of these Vessels visibly evinces the Filtration made there of the contained Liquid, and the Coats and Cavity of this Organ are nothing else than the Prop and Reservoir of it.

The Inside of the Glands is the Concourse of arterial and nervous Extremities; in which Concourse the animal Fluid is united to a volatile Part of the arterial Blood, to enable it to discharge its Functions. This Union is made by Means of the nervous and vascular Tufts. These Tufts in the Eye produce the Down of the Choroides. It is therefore highly probable, that the black Liquid with which this Down

A Physical Essay

is imbued, is nothing else than the sulphureous Particles of the Blood diffused in this Texture by the Tufts of the Arteries, and loaded with the volatile Portion that is mixed with the animal Fluid, conveyed by the nervous Tufts.— Or, if you please, this black Liquid is the Dregs as it were of the Fluid, that results from the Mixture of the Spirits with the volatile Part of the Blood. The animal Fluid partakes in some Degree of the Nature of Mercury. Now Mercury, intimately united with Sulphur, forms a black Substance, an *Æthiops*, as every body knows. In like manner there is all possible Room to imagine, that the Eye presents to us sensible Traces of this so useful Mixture; which we establish on no other Basis than that of the Necessity there seems to be for it, in regard of almost all the Functions, and principally of muscular Motion.

However, this black Liquid observable in the Choroides is not peculiar to the Eye; we meet with it on the Inside of almost all the Glands. It is visible in the Glands of the Kidneys; for which Reason they are called *Capsule Atrabiliarie*. It is likewise visible in the pulmonary or bronchial Glands. It is this same Liquor which is evacuated in the black Vomittings that accompany those extreme Maladies, which I term the convulsive Dissolutions of the nervous System; by reason that the Violence of the Depravity is such, that the Inside of the Glands

Glands of the Stomach and Intestines is stript of this black Liquid. Vomitings of this Sort are more frequent in Children, because the nervous Extremities which form their Glands, are softer and more open. In short, the Colour of Negroes has no other Origin than this sable Liquor, with which their cutaneous nervous Tufts, being very porous, imbue the Cuticle that invests them.

The
E. Y. P.

The Down of the Choroides, impregnated with the Liquid we have been speaking of, forms, as we have seen, the inner Membrane of the Choroides. The exterior Lamina this is sustained by, is in the Organ of the Sight, what the Corpus Reticulare is in the Organ of the Touch, and in that of the Taste. In all these Organs, the Vessels and Nerves, before their Expansion into Tufts, are stripped of their thick Coat; and it is of these Spoils the Texture is formed, which in the Eye constitutes the exterior Tunic of the Choroides. The nervous Papillæ being stripped in like manner, become more delicate, and endued with a greater Sensibility; and the Texture made of their Spoils serves to sustain the nervous Tufts and Orifices of the Vessels that convey the necessary Liquids as well to the Papillæ themselves, as to the transparent Humours contained in the Globe.

As far as the Choroides, the Vessels are large enough to permit the sulphureous Particles of the Blood, I have been speaking of, to pass along

The
E Y E.

with the spirituous Lymph. But, beyond this Membrane, the Minuteness of the Vessels lets only an extremely subtil Lymph escape, which forms and supplies the Humours of the Eye.

Of these the *Vitreous Humour* is the most considerable. It fills about three Fourths of the Globe of the Eye towards the Bottom of that Organ, and is condensed to a Jelly; because being embraced by all the Coats of the optic Nerve, and immediately by the medullary Part of it, the Retina, it is impregnated with a great Quantity of this enlivening Liquid; the Property of which is to give a Firmness and Consistence to the Solids and Fluids, where it occurs in Abundance.

The *CrySTALLINE Humour*, for the same Reason, ought to have this Consistence in a greater Degree. For besides the preceding Advantages which it has in common with the vitreous Humour, its very small Circumference receives likewise by means of the Corona Ciliaris the Concourse of all the nervous Extremities of the Choroides. It must therefore be impregnated with a greater Quantity of this Fluid, and consequently acquire a larger Proportion of Consistence.

For the contrary Reason, the Liquid situated under the transparent Cornea, and remote from this great Influx of the conservatory Fluid, must fall short in Point of Consistence, and make a Fluid of an aqueous Nature.

What

What is very surprising, is the Disposal of these Causes, to produce Effects so singularly peculiar to the Organ they compose. A glandulous Papilla of the Tongue is but the Extremity of a nervous Fibre. This Fibre could only make a porous Button, full of a limpid Liquid, which, indeed, was all it was necessary it should do. But this would no ways have been sufficient for the Organ of the Sight; more Materials were requisite. Besides, it is not here a nervous Fibre, but an intire Nerve, and that a very considerable one, which expands itself at once into a single Papilla, and by its thick Coats forms a perfect and intire Globe, that one would almost imagine to be impenetrable even to Light itself, which, however, is not fact. The exterior Coat, which is the only one thick and substantial enough to compleat the Circumference of this Globe, is naturally disposed to terminate in a transparent Lamina; and this Lamina occurs precisely at the Entrance of the Rays. Because, physically speaking, it can occur only at the Extremity of this nervous Body, as the Nails can be formed no where else but at the Ends of the Fingers.

The Cornea then in this Metamorphosis does not at all contradict its Origin, but follows the common Law of the Nerves. The farther they recede from their Beginning, the harder they grow, and compacter. The Nails are formed by the Extremities of the Nerves of the Arms

The
E Y E.

and Legs. These Nails are hard and transparent; and would be as transparent as the Cornea, if, like that, they were incessantly moistened with Liquids. The Cornea becomes as little transparent as the Nails, when it is once abridged of its usual Supply of Moisture. Therefore these two Parts have the same Nature and the same identical Origin.

The Rays transmitted to the Eye stand in need of being there refracted, and collected after a particular manner: and an uniform Liquid, like what is contained in all the glandulous Papillæ, could not have effected that Business agreeably to this Organ. Now the inner Substance of this large Nerve has provided for this Contingency! It is the Stream of a Fluid, which gives Consistence and Solidity to all our Parts; and its Distribution is such, that it imparts this Consistence precisely in the Order which the Perfection of the Organ demands. And in the mean Time, for such a Prodigy of Execution, what a Simplicity of Mechanism! A Nerve expanded into a Globe, its Coats distinctly spread one over another, Liquids collected under these Coats by a very ordinary Filtration; this is the whole Apparatus!

O admirable first Cause! with what Rapture ought the Mortal to be seized, who discovers demonstratively the Simplicity and natural Chain of Springs, with which such a Series of Wonders is produced!

An

An infirm Production, termed *Hydatides*, The
 the Mechanism of which I have had Occasion to E. Y. E.
 unravel, seemed to me to be a Sort of rough
 Draught of the Formation of the Eye, proper
 to confirm that which I have been delineating.
 The *Hydatides* I examined, were very brittle mem-
 branous Globes, filled with a Humour, a small
 Portion of which was glutinous like the vitreous
 Humour, and the greater Part liquid and trans-
 parent, like the aqueous Humour of the Eye.
 Their Size was from that of a Pea, to the
 Bigness of a Egg. They were contained in the
 Duplicature of the Membranes of the Liver and
 Spleen. And, from the State of the Parts af-
 fected, it seemed to me evident, that this pro-
 digious Number of small liquid Balls were
 formed by the glandulous Papillæ of the Sur-
 face of these Viscera; which, retaining thro'
 some Indisposition the Lymph conveyed in
 their interior Texture, had been distended by
 this Lymph, and so had formed these watery
 Bubbles. We have already seen, that the Eye
 is only a nervous Papilla, that retains its filtra-
 ted Liquors. So that an *Hydatid* resembles in
 some Measure a defective Eye, and an Eye an
Hydatid very perfect, sound, and compleatly
 organized. In a Word, an *Hydatid*, in rela-
 tion to the Eye, seems to be what a Mola, or
 false Conception is in regard of a Fœtus.

The Eye then only differs from other glandu-
 lous Papillæ, inasmuch as this Organ is formed

of

The
E. & S.

of an intire Nerve, and contains in its Inside all the medullary Substance, all the spirituous Fluid of the *pia Mater*, all the Fibrillæ of this Part destined to constitute the simple Papillæ, and all the Fluids accustomed to associate themselves in the nervous Papillæ. This inner mammillary Texture is what was above described in the Choroides, and assigned as the immediate Organ of Vision, in Conjunction with the nervous Texture that sustains it, that is to say, with all the Laminæ of the *pia Mater*. This immediate Organ of the Sight has raised a great physical Controversy.

The prevailing Opinion, that Sensations are conveyed to the very Substance of the Brain, has been the Reason why the immediate Organ of Sight has hitherto been placed in the Retina, which is an Expansion of the Substance of the Brain contained in the optic Nerve. The ingenious *Monf. Mariotte*, so accustomed to fathom the Secrets of Nature by Experiments, was even himself surprised, that the medullary Part of the optic Nerve should be incapable of Sensation *.

Experi-
ment of
M. Mari-
otte, on
the imme-
diate Or-
gan of
Sight.

This learned Naturalist was likewise a very dextrous Anatomist. He was sensible the optic Nerve was not expanded in the middle of the Bottom of the Eye, but a little above it, and on one side towards the Nose. So, willing to know the Consequence in case he made the Image

* Journal des Sçavans 1668.

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Plate.VII.

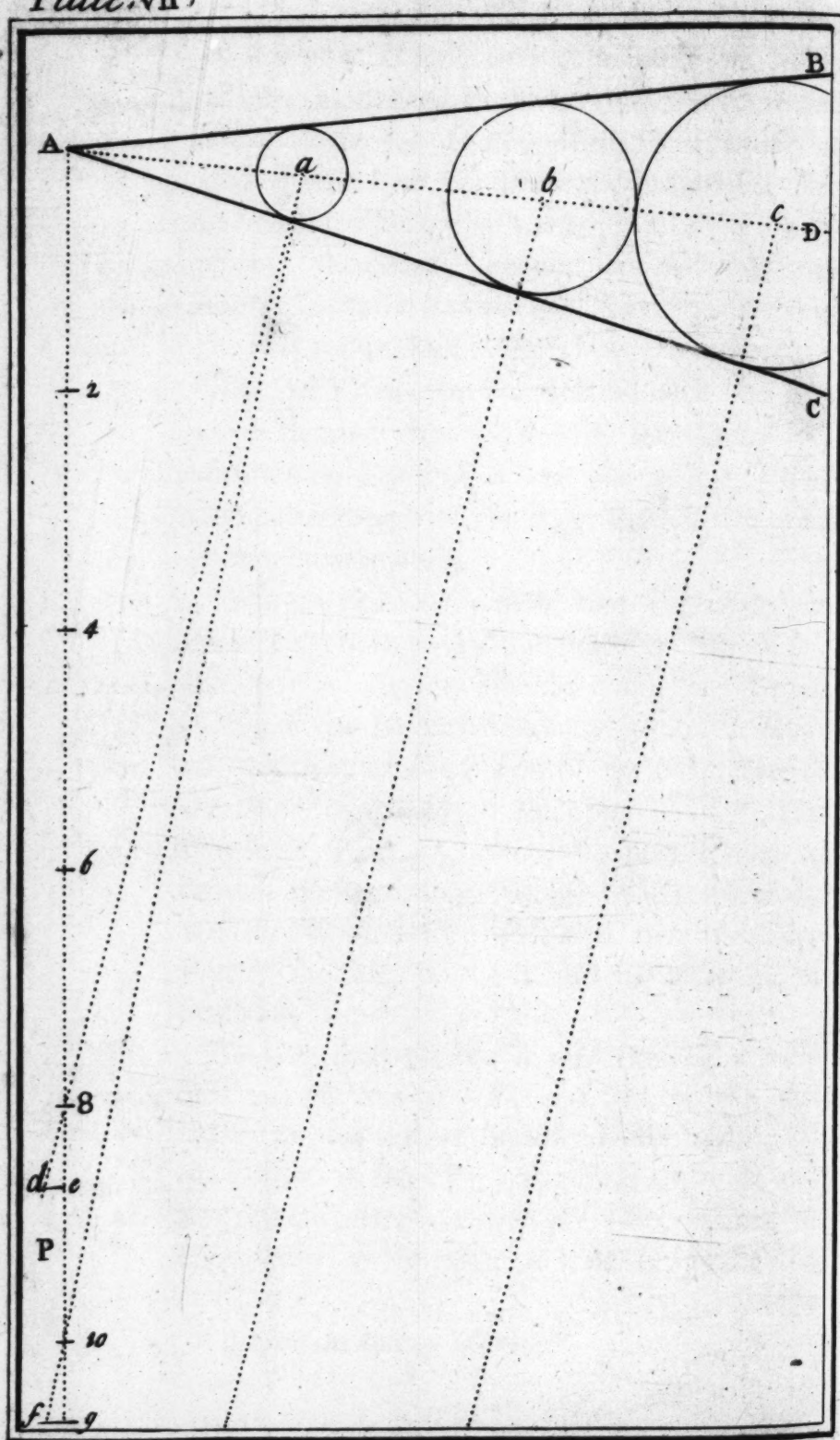


Image of an Object fall directly on the medullary Substance of the Nerve, he placed at first a Piece of white Paper the Height of his Eyes, to serve for the Point of fixed View. He shut his left Eye, and determined only his Right to his Experiment. After that he placed a second Paper at two Feet Distance from the former, on the right Side and a little lower, that the Image might fall directly upon the optic Nerve of the right Eye. After this Apparatus, he placed himself over against the first Paper, with his left Eye shut, and his right fixed on this Paper. He then saw them both. He therefore drew back by little and little, in order to make the Image of the second Paper fall upon the optic Nerve. When he had retired the Distance of ten Feet, this was actually accomplished, for the second Paper intirely disappeared. He imagined at first that his having lost Sight of the Object was owing to the Obliquity of it; but he observed he saw other Objects that were still more remote from the first Paper, and consequently more oblique. He repeated his Experiment, examined it from every Point, and was confirmed in the Discovery he had been making, that the Object disappeared every Time the Image fell directly on the optic Nerve.

I have myself recurred to Mons. *Mariotte's* Experiment; which succeeded with me on the very first Trial, only with this Difference, that
it

The it was at the Distance of eight Feet I lost
EYE Sight of the second Paper that was placed two
 Feet from the first. Either farther or nearer
 than eight Feet, the second Paper presented it-
 self to my View.

I did not at all confine myself to this simple
 Experiment. Instead of the second Paper I
 lost Sight of, I made use of a large Sheet of
 Paper, and observed that at this same Distance
 of eight Feet, I lost Sight, in the Center of
 this Paper, of a circular Space of about nine
 Inches Diameter. I made the same Experi-
 ment, at all Sorts of Distances, but shall give
 an Account of those made at three only, which
 will be sufficient to establish a general Rule.
 See Plate VII.

The first Paper, where the Point of fixed
 View is in A, for all the Experiments.

In the first Experiment, the second Paper (a)
 is at two Feet Distance, as before mentioned.

The Eye (8) is at the Distance of eight
 Feet.

The dark Circle (a) is nine Inches Diameter.

In the second Experiment, the second Paper
 (b) is at the Distance of four Feet.

The Eye is at that of sixteen Feet.

The dark Circle is eighteen Inches Diameter.

In the third Experiment, the second Paper
 (c) is at the Distance of six Feet.

The Eye at that of twenty-four.

The

The dark Circle is twenty-seven Inches, or two Feet three Inches Diameter. The
Eye.

From these several Experiments result the following Corollaries.

Generally, to make the second Paper disappear, it must be placed on one Side, and a little above the first, at a Distance from the Eye of about a fourth Part of that of the first Paper.

In Proportion as the Eye recedes from the Point of View, A, the dark Circle retires likewise towards D of the same Point A, and is enlarged to a Degree corresponding with this Distance.

Hence this Series of dark Circles, a, b, c, and all those that are to be supposed to be between these, form the dark Cone B, A, C, that makes an Angle of almost twenty-four Degrees. Its upper side A, B, is almost five Degrees above the horizontal Line or right Angle, taking Measure from the Perpendicular A, P, which makes here the visual Axis. The Axis A, D, of the dark Cone is about seven Degrees below the horizontal Line or right Angle. It passes thro' the Center of all the dark Circles, and so is thought to go thro' even the Center of the optic Nerve, at whatever Distance the Eye may be from the first Paper A. Consequently, it may be determined by this Axis, how much the Center of the optic Nerve, or its Axis, is below the visual Axis. For the more the Axis A, D, of the dark
Cone

The
EYE

Cone declines below the horizontal Line, the more the optic Nerve is below the visual Axis, by reason that the Rays cross one another, and are confounded in the Eye.

One may determine likewise by these Experiments, how far the optic Nerve is distant from the visual Axis towards the Nose.

Rule to determine how far the optic Nerve is distant from the visual Axis

The Perpendicular A, P, represents the visual Axis. It is the Line according to which the Eye is placed and directed towards the fixed Point A. The pointed Lines, which from the Center of the dark Circles, a, b, c, pass thro' the Points of the Stations of the Eye, terminate in the Center of the optic Nerve, and delineate the Axis of this Nerve. These two Axes, that is to say, the visual Axis A, P, and the Axis of the optic Nerve a, d, cross one another on entering the Eye at the Point marked 8, by the first Experiment that I made; and at the Point marked 10, by that made by M. Mariotte. Consequently, the Opening of the Angle d, e, formed by this Crossing, is with me the Measure of the Distance of the visual Axis from the Center of the optic Nerve: and the Opening of the Angle, f, g, would measure this same Distance with M. Mariotte. So that since my Eye must be at the distance of eight Feet (8) to lose Sight of the second Paper, a, while Mariotte lost Sight of it at ten Feet Distance, (10) it is a Demonstration, that my optic Nerve recedes about a fifth farther from the visual

visual Axis, than did that of M. Mariotte; because the Triangle, d, b, c, resulting from my Station, has a Basis about a fifth narrower than the Triangle, Fig. 10. g, which results from Mariotte's Station.

The
Eye.

The dark Circle is nine Inches Diameter, when the Eye is at the Distance of eight Feet; eighteen Inches, when the Eye is sixteen Feet distant; and would be thirty-six Inches Diameter, were the Eye at the Distance of thirty-two Feet. The dark Circle of three Feet is the Portion of the Image which falls upon the medullary Center of the optic Nerve. This medullary Center at the Bottom of the Eye is no larger than a small Pin's Head, or the third or even fourth Part of a Line. So that at thirty-two Feet Distance from us, a Yard of Space is included in an Image of about a Quarter of a Line. What would it be, were the Objects several Leagues distant? How many thousand Feet of Space crowded into the fourth Part of a Line! For Instance, I am on the Top of Montmartre: all Paris, that immense City, and the Extent of Plain that surrounds it, with its magnificent Palaces, are actually painted sufficiently distinct in the Bottom of my Eye. Here the Horizon comprizes about seven Leagues, and the Bottom of my Eye seven Lines. It is a League of Country for every Line, and a Quarter of a League for the fourth Part of a Line, which I before hinted.

To what a Minute-ness Objects are reduced in the Eye.

This

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Ex 2.

This Reduction of seven Leagues of Country, to a distinct Image of seven Lines, is undoubtedly wonderful. It is astonishing even at first to the Imagination, tho' no ways repugnant to our Reason, nor, indeed, surpassing its Lights. Were one inclined to exceed the Truth, on this Head, and talk in the miraculous Strain, the Gasconade would be easily detected. We have seen Landscapes of a very large Extent, brought by our Painters into the Compass of a Foot of Canvas. I have seen such in the Space of an Inch, and even in the Compass of the Signet of a Ring. Nobody is ignorant what a Difference there is between the Size of a Painter's Pencil, and the Filaments of Light that enter the Eye. We are therefore soon recovered from our Astonishment, and comprehend clearly how much Nature surpasses, and ought necessarily to surpass, the Productions of Art.

A large
invisible
Circle sur-
rounds
every
thing we
see.

From the well-grounded Existence of the dark Circles, which I have been speaking of, I make this farther Conclusion, that, in respect of every thing we see, there is on each Side of them a large Circle intirely hid from us. A one-eyed Person in particular loses a considerable Part of the Objects that present themselves, if he looks on them at never so little a Distance. The Quickness of the Motion of the Eye remedies in a small Degree this Inconvenience, by taking a successive Survey of every Object; but it does not intirely repair it. The Point of

Shade

Shade every where attends the Eye, and for the same Reason that it passes the Objects in Review, it must also cast a successive Eclipse on several of them.

The only Consequence, M. *Mariotte* had a Mind to draw from this Experiment, is to strip the optic Nerve of the Function of being the immediate Organ of Sight, and the Matter seemed to be a Demonstration. But independent of this very striking Observation on the Impotence of the medullary Part of the optic Nerve, what we learn from Surgery, concerning the Insensibility of the Substance of the Brain, seems necessarily sufficient to make us conclude, that the medullary Part of the Nerves cannot be the Organ of any one Sensation, nor consequently of Vision. In the mean Time this single Experiment had not Force enough against an established Opinion. A thousand Subterfuges might have been opposed to it. It would, perhaps, have been granted, that the medullary Substance of the Brain and Nerves is insensible to the cutting of a Knife, but not so, it might have been urged, to Light proportioned to its Delicacy. Therefore Facts were necessary, such as M. *Mariotte's* Experiment, to render the Opinion of the Partisans for the Retina suspected of Error; and M. *Mariotte* wanted a Person of M. *Mery's* Genius and Disposition, to evince, by profound anatomical Researches, what the Naturalist had began to

M

establish

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EYE.

Sequel of
the Proofs
against the
Retina.

**The
E Y E.** establish by an optical Experiment. M. Mery plunged a Cat in a Pail of Water, and examined the Bottom of her Eyes; the internal Parts of an Eye, when plunged in Water, appearing more distinctly. He saw on this Occasion, that the Retina was as transparent as every Humour of the Eye, and concluded from thence, that this Membrane was no more the immediate Organ of the Sight, than the crystalline and vitreous Humours; as the Rays pierced it as easily as they pierce the other Humours.

Objections
and An-
swers.

Subterfuges nevertheless are in the mean Time opposed to all these demonstrative Proofs. First, the Retina, it is urged, in spite of its Transparency, has a Sort of Opacity almost like that of oiled Paper. Take the Eye of an Ox, separate the Coats from the Bottom of it, close by the Retina; place this Eye at the Hole of the dark Chamber, and the Image of Objects will be painted on the Retina, notwithstanding this Separation of those Coats.

This little Opacity of the Retina is a Proof that it intercepts a small Matter of Light, that it softens the Impression of it, but not in the least that it is the Organ of Vision. On the contrary, as the Retina intercepts but a very minute Portion of Light, suffering almost all the Rays to pass, it cannot be the Organ of Sight. Because an Organ ought to put a Stop to the whole Object, and fix it intirely. This
Organ

Organ therefore is rather the Membrane, on which the Retina lets all the Light that escapes itself fall, to be absolutely absorbed by this second Membrane.

The
EYE.

Secondly, two Replies are framed to our famous Experiment from the dark Circle, which falls on the Center of the optic Nerve.

M. *Pecquet* asserts, that it is a Trunk of a Blood-Vessel, that occurs in this Place in the Retina, and intercepts the Action of the Ray.

But it is evident, that Light freely pierces our Solids and Fluids; particularly when they partake of such a Degree of Fineness, as we find they have in the Retina. Without this Circumstance, what Darknes would there not be in an Image! What a System it is they adopt! Because the Retina has a considerable Number of Vessels thro' the whole Extent of it; so, according to M. *Pecquet*, thro' all the Course of these Vessels, Light would make no Impression either on the Retina, or on the Choroides that is behind the Retina. In the mean while this Darknes is contradicted by Experience.

Monf. *Perrault*, in his Turn, says, that the Retina, being transparent, stands in need of the Choroides to reflect back the Rays on it, as a Looking-Glass requires Quicksilver; and that at the Centre of the optic Nerve, the Retina being unsupported by the Choroides, is like

The
EYE.

Glasses, whose Quicksilver had in some Part been peeled off.

This Academist compares the Choroides to the Quicksilver of a Looking-Glass, whereas it precisely produces a quite contrary Effect. The Office of Quicksilver is to make a lively Reflection of Light; the Choroides, on the other Hand, is a black Down, which totally absorbs this Light, and consequently can remit no Sensation of it to the Retina. He is obliged to own, that, where the Choroides is defective, there also Vision fails; and that thus the Choroides is an Organ as essential to this Sensation, as Quicksilver is to the Effect of the Looking-Glass, which is the Reflection of Images. I admit the Comparison in this Instance. It is the Quicksilver alone that reflects the distinct Image we believe we see in a Glass; it is that alone, which produces the intire Effect of the Mirrour, the Glass of which serves only to fix the Quicksilver, and to let the Rays pass. In

The Choroides is the immediate Organ of Sight.

like manner, it is the Choroides that performs all the Function of Vision, and that is the Seat of this Sensation; and the Retina is no more than the Glass that lets the Images pass. What other essential Function can be attributed to the Choroides in Vision, than that it should be the immediate Organ of it?

Besides, in the Choroides are assembled all the Qualities requisite to form the Organ we are in quest of. It is a Continuation of the *pia*

Mater,

Mater, which we discovered above to be the real general Organ of Sensations. The Choroides is solid, elastic, and extremely sensible. It is furnished with a Sort of black Down intirely adapted to absorbing of Rays, or Images, and consequently receiving the whole Impression of them, and that distinctly. We above observed, that the Papillæ of the Tongue absorb the savoury Juices; that the Inside of the Nose retains the odoriferous Vapours, &c. It is almost the general Structure in the Organs of Sensation, and there is no one where this Structure is more essential, than in the immediate Organ of Sight. Because in case this Organ had not absorbed the Image, and reflected it, this reflected Image had been scattered thro' this whole Concavity, all the Parts of this Concavity had produced similar Reflections, and there would have been, all thro' the Organ, a strange Confusion of Rays, and of Impressions, without any Image, or distinct Sensation. It is partly for this Reason, that old People, in whom the black Liquid of the Choroides falls short of its fine sable Colour, discern not Objects so clearly as formerly, but with a Sort of Confusion. The Choroides therefore is the sole Membrane of the Eye proper to constitute the immediate Organ of Vision.

When we would examine the Goodness of an Eye, we place the Person over against a fine Light, and close both Eyes. We then suddenly

The
Eye.

open the Eye we have a Mind to examine. We next remark the Motion the Iris makes on the Entrance of Light into this Organ. If it contracts itself a good deal, the Eye is very good; if but a little, it is an evident Sign it sees but feebly; and should it remain immoveable, it is absolutely deprived of Sight.

A good Eye contracts its Pupil, by reason the immediate Organ of Vision is attacked by a lively Light, that stimulates it, and determines its Fibres to shorten themselves. The bad Eye continues immoveable, because a bad Eye is that which is no longer sensible of the Impression of Light; which Insensibility is the Reason why it is not excited to a Contraction of its Fibres. It is therefore the same Organ, which perceives the Impression of Light, and that contracts its Fibres in Consequence of it. Now the Iris, which contracts itself likewise, is the Continuation of the Choroides, and has no manner of Connexion with the Retina. Therefore the Choroides is the immediate Organ of Sight.

It sometimes happens, that, in an Eye that is lost, the Iris will have a small Motion, on opening the sound Eye to a glaring Light. The Iris of the lost Eye contracts itself on that Occasion thro' the Sensibility of the sound Eye, which determines a small Portion of the Fluid that causes the Motion to flow in the Nerves of the other, where some Pipes of this Fluid remain still open, tho' all the Canals of the sensi-

tive

tive Fluid be intirely shut up; because those are of another kind, and of a considerably finer Texture, as we have seen.

The Accidents, which befall the Eyes, are farther Proofs on the Part of the Choroides. In case an Inflammation, or painful Tension, affects the Eye, the immediate Organ, endued thereby with too great a Sensibility, finds itself hurt by the ordinary Light, and sufficiently agitated by the most feeble Rays, as we have seen by the Observations of those Persons, who can discern Objects in the dark. But, of all the Parts of the Bottom of the Eye struck by luminous Rays, the Choroides alone is susceptible of Pain, Tension, and Irritation; inasmuch as the Retina is only a soft and insensible Substance. Therefore the Choroides is the immediate Organ of Vision.

To what Purpose then serves the Retina? It serves, first, to give to the vitreous Humour, and the Crystalline it embraces, their remarkable Consistence. Secondly, to convey to the Corona Ciliaris, the Fluid that is the Principle of Action, pursuant to the ordinary Use of the Center of the Nerves, and of their medullary Substance, which constitutes the Retina. Thirdly, to perform on the Choroides the Function attributed to the Cuticle that covers the Papillæ of the Organ of the Touch, or to discharge the Office of the porous Membrane covering the glandulous Papillæ of the Tongue.

The Eye. That is to say, the Retina receives the Impression, moderates it, and fits it, if I may be allowed the Expression, to the Unison of the genuine Organ. But, in receiving this Impression, it is no ways sensible of it. The Image is represented on the Retina, as on an oiled Paper. It is not the oiled Paper that discerns the Image, it is the Eye, the Organ that is behind the Paper.

Let us quit for a Moment the Inside of the Globe of the Eye, and survey the Machines that are disposed around this Organ for the Perfection of its Functions.

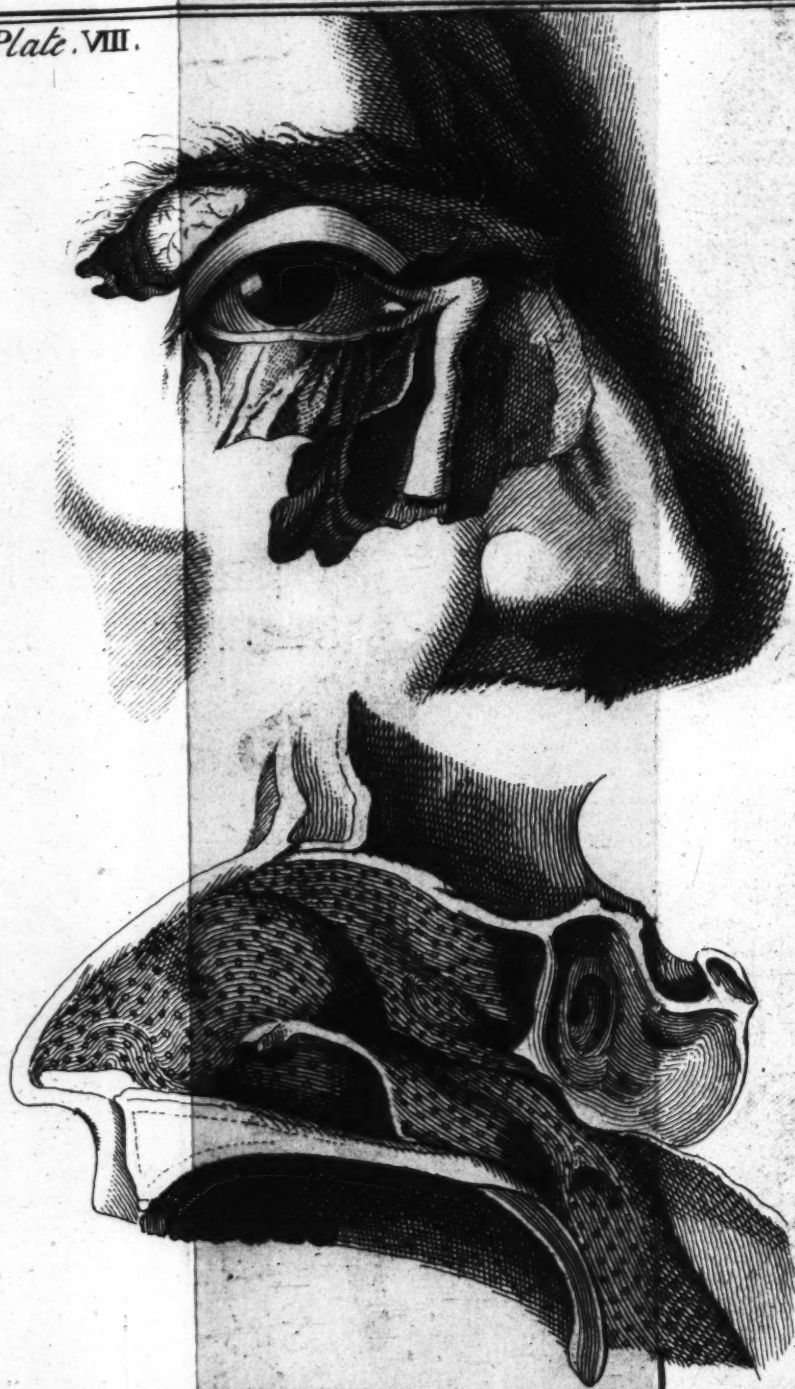
The Glass, which makes the Entrance of the Globe of the Eye, is not a solid Crystal. It is, it must be owned, a hard and polished Membrane, but it is still a Membrane, and owes all its Smoothness and Transparency not only to the aqueous Humour it contains, but also to another limpid Water that incessantly moistens it without, and exactly fills its Pores. Deprived of this Water, the transparent Cornea being exposed to the Air grows dry, shrivelled, tarnished, and ceases to let the Rays pass. This Water so essential to the Transparency of the Cornea, and to Vision, is the Tears.

For the Source of this Liquid is assigned a complicated Gland, situated on the external and upper Part of the Eye, called the *lacrimal Gland* *.

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* Consult, on the Head of this whole Description, the Figures of Plate VIII.

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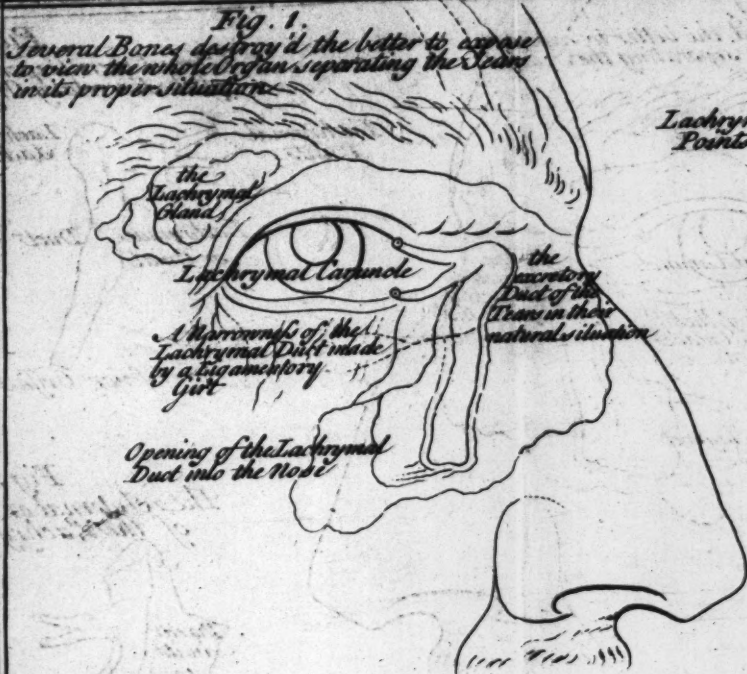
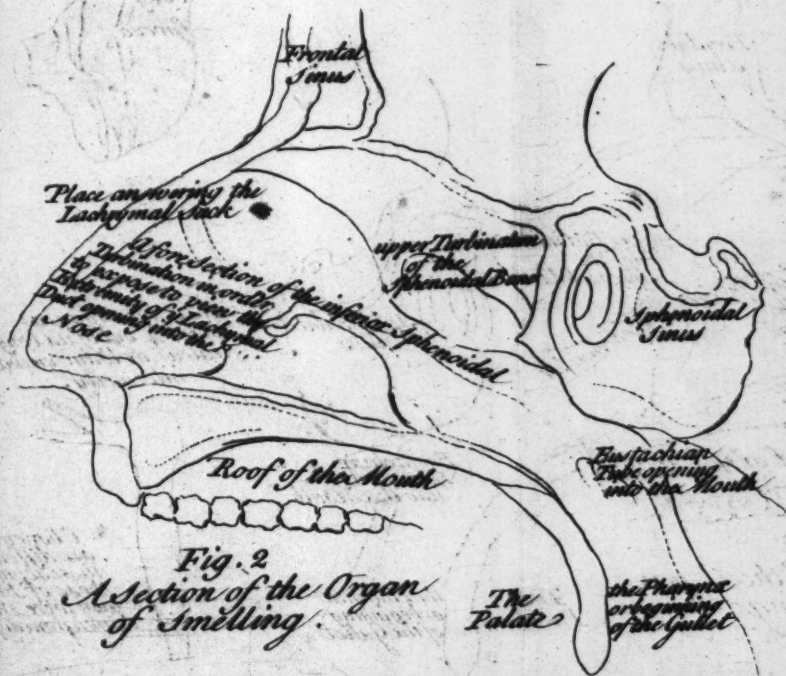
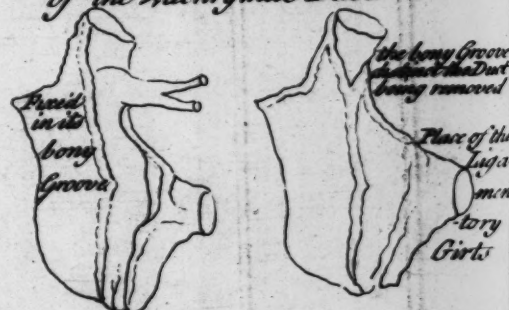


Fig. 3.
A Front view (separated from the Body)
of the Excretory Organ of the Tears.

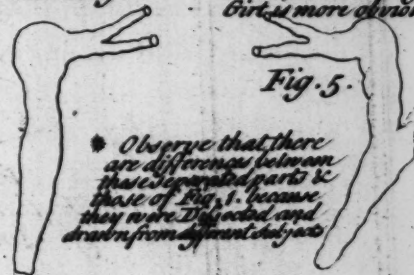


Fig. 4.
The Internal or Posterior View
of the Lacrymal Duct



The same Organ as
in fig. 4. out of its bony
Sulcus, or Ridge removed
internally.

The same Organ seen on
the right side suffering
the Lacrymal Points
to fall forward thus the
Structure made by the
Girts is more obvious.



The Tears are shed on the fore Part of the Eye by very fine Conduits; and the frequent Motion of the Eye-Lids scatters them, and by that means waters all the polished Surface of the Eye. They are afterwards conveyed towards the Angle pointing to the Nose, or the grand Angle, by the twinkling Edges of the Eye-Lids, which separately do the Office of a Gutter, and jointly the Office of a Canal, and at the same Time that of a Piston or Sucker of a Pump.

On each Eye-Lid towards this great Angle, where the Tears are conveyed, we meet with a Sort of small Reservoir, the Orifice of which is termed *Punctum Lacrymale*. Each of these minute Canals are united at the great Angle with a common Reservoir called *Saccus Lacrymalis*. This Bag is attended by a Canal, named the *Lacrymal Pipe*, which descends lodged in the Bones even to the Nose; where it disperses the Tears that concur to moisten this Organ, when they flow not in too great Abundance. But, on weeping, there is a Necessity of frequently blowing the Nose, in order to disembarrafs it of the Tears, which there flow at that Time in too great a Quantity.

It was not at all sufficient, that the Globe of the Eye should be watered in order to preserve its Transparency and Beauty; it was necessary likewise that these Telescopes of the Soul should

The Mus-
cles of the
Eye, their
Use, and

The
Eye.

be directed towards the Objects we would take a View of; and that they should be dilated to receive distinctly the Images of neighbouring Objects, and contracted for the receiving those of Objects at a Distance, for Reasons we shall see by and by. Now all these respective Motions depend on six Muscles, surrounding the Globe of the Eye *. Four of them direct it in its strait Motions, upwards, downwards, and sideways. These four principal Muscles, acting in concert with the two others, perform the oblique Motions.

These Muscles rise from the Circumference of the optic Hole at the Bottom of the Orbit, thro' the Angle formed by the Division of the two Laminæ of the *Dura Mater*; one of which of considerable Thickness, invests the optic Nerve, and the other, very fine, lines the Orbit, as has been already hinted. These Muscles do not, as is generally the Case, derive their Origin from some Bone. Their tendinous, or rather nervous, Beginning, is visibly a Part, or a Production, of the exterior Lamina of the *Dura Mater*; which is only of that Thinness, because these Muscles are produced at that

The Bones
and Mus-
cles are
the Pro-
duction of
the *Dura*
Mater.

Membrane's Expanse: which, I make no manner of doubt, has produced likewise the Orbit, lined and nourished by its exterior Lamina. For to nourish a Part, to give it Accretion, and to form it, seem to me three Things consequent to one

* See Plate II.

one another. What the *Dura Mater* does in regard of the Eye, it performs in respect of all the rest of the Machine. It accompanies the whole nervous System, and lines all the Bones under the Name of the Periosteum: and it is from these Periosteae, that the Muscles take their Rise. It is the Reason, why Parts supplied with the most substantial Nerves, as the Thigh, are furnished likewise with the most considerable Bones and Muscles. Ours is analogous to the Formation and Accretion of Vegetables. One sole Principle extended, unfolded, and varied, forms every Species of Parts. From the Root of the Plant springs the Trunk, the Branches; the Leaves, Flowers, Fruit, and their respective Parts. From the Brain and Nerves is every thing formed in Man. His Mechanism is of a more complicated Nature, but still it is really Mechanism.

All Parts
of the animal
Spring
from the
Brain.

Generally all the Muscles of the Eye correspond in their Motion, and determine at one and the same Time the Axis of each Eye towards the same Point, towards the same Object; and this ordinary View is called a *direct Sight*. Sometimes the Eyes are in such a State, that there is no directing both of them in a strait Line towards the Object they are fixed on, which Circumstance is termed Squinting. This Defect proceeds from the Equilibrium being broken among the preceding Muscles, whether by Accident, or determinately. The Equilibrium

Squinting
Eyes.

The
Eye.

Equilibrium is destroyed among the Muscles of the Eye, first, by reason that one of the Muscles is weaker than the rest, occasioned either by a paralytic Disorder of the Nerves, or by a Sort of Sprain of this Organ consequent to some violent Motion. Secondly, Squinting arises likewise from one of the Muscles contracting itself in a greater Degree than the others, thro' an acquired Habit of forcing the Eye in the Direction of this Muscle. This is the most ordinary Cause; and it is thus that Infants in the Cradle, excited by some Object or other to turn an Eye strongly sideways, contract this ill Custom of Squinting. We shall assign hereafter an additional Cause of this Defect.

Let us see, in the mean while, how the Images of external Objects come to be painted in this wonderful dark Chamber, accommodated with its Lens's, and a Texture, that not only receives these Images, but even perceives their Impression.

We have seen, that the Action of Light consists in the Vibrations of this Fluid excited by luminous Bodies, and reflected by Bodies visible. A Body is not seen, but inasmuch as it reflects these luminous Vibrations back to our Eyes. It is only the Sun, and luminous Bodies, that become Objects of Vision by Vibrations immediate and without Reflections. These Vibrations, reflected by illuminated Bodies, are quick and lively, when they shoot from the Surfaces of Bodies, which reflect a great deal of Light;

How Objects are painted in the Bottom of the Eye.

The
EYE.

Light ; or that are at the regular and direct Point of Reflection, explained p. 100, &c. These Vibrations are feeble in Proportion as the Reflection is more indirect, more oblique, and less supplied with Rays ; and it is this more or less of reflected Light, which forms the Image of Bodies.

For the Parts of the Surface of Bodies, which we receive the regular Reflexion of, constitute the luminous Points of their Images. The others, which dart on us a more or less oblique Light, form the Gradations, Mixtures, and Shades of these Images. In short, Light delineates on the Choroides, as we delineate on a black Paper, in Crayons, white, grey, &c. We put white, that is, a great deal of Light, in those Parts of the Piece which ought a good deal to project, and appear in a strong Light. Grey, or, in other Words, a small Portion of Light is placed in the Parts, which ought to project less and appear more obscure ; and, in short, the Paper is left all black, that is, no Light at all is displayed on the Places that should be intirely dark.

In order to form an Idea how a Body diffuses its Image to all Distances, and in all the Points of Space that surround it, we must look upon all the Particles a visible Body is composed of, as so many small pyramidal Mountains, every one of which scatters a Sort of Atmosphere of Rays towards all the Points of Space with which this Part of the Body corresponds.

How the
Image of
an Object
occurs in
all the
Points of
Space that
surround
it.

Each

The Each Particle or each Point of the Body making
BY a like scattering of Rays, all these Rays must necessarily cross one another, meet one another, and unite in all the Points of Space that surround the Body. Now as from all the Points of Space surrounding a Body, there is effected a Union of Rays reflected from every Point of the Object, there is also produced an Image of this Object. For the Image of an Object is nothing else than the Union and Assemblage of Rays reflected from all Points of the Surface of this Object. In order to give a sensible Idea of this Scattering, Crossing, and Union of Rays, see Fig. 1. where we have taken only three Points of the Object, and have scattered of those but a few Rays, not to embroil and confound the Figure. All the Points, o, of the Circumference of this Object, where the three Sorts of Rays unite, are those where the Object is visible. Now naturally, this Union is in all the Points of this Circumference, as the Number of scattered Rays is in a manner infinite.

I conceive, you will tell me, that when the Rays of the Sun from the South go to strike an Object placed in the North, my Eye, situated Southward of this Object, will receive its Image. But how shall I receive this Reflection and this Image, if the Object be between the Sun and me? And yet, notwithstanding, I do not at all cease to see it in this Situation.

You

You see it! Therefore you receive the reflected Rays of it. You do not receive the immediate Reflection of the Rays of the Sun, but that of the Rays, which, having passed this Object, and having been struck by other Bodies, the Air, and perhaps yourself, have been reflected from thence towards this Object, which transmits them to you in its Turn. For altho' the Action of the Sun, and of all luminous Bodies, has but one sole Direction, yet Objects reflect Rays in all Directions, and from every Point of their whole Circumference. Because this first Direction, imprinted on Rays by luminous Bodies, is varied in a thousand and a thousand other Directions, by the innumerable Reflections which these Rays undergo from all the Bodies, and every kind of Matter, that occurs to them.

Let us take one of these Points, where these three Sorts of Rays cross one another, and there place an Eye, Fig. 2; Plate IX. The Ray A, a, that darts from the Point of the Arrow, A, B, in passing from Air to the transparent Cornea and aqueous Humour, passes from a less dense Medium to one that is more dense. It must therefore be refracted in approaching the Perpendicular, p. 1; the inferior Ray, B, b, does the same. The Rays approach one another, and are collected in a less Space in order to pass thro' the Pupil.

In

What arrives to the Image that passes thro' the Eye.

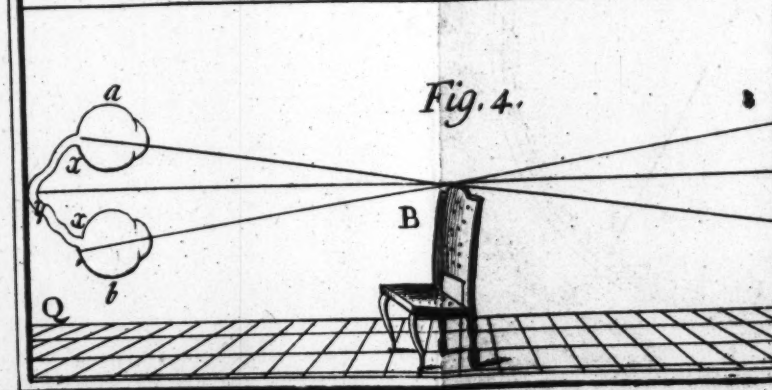
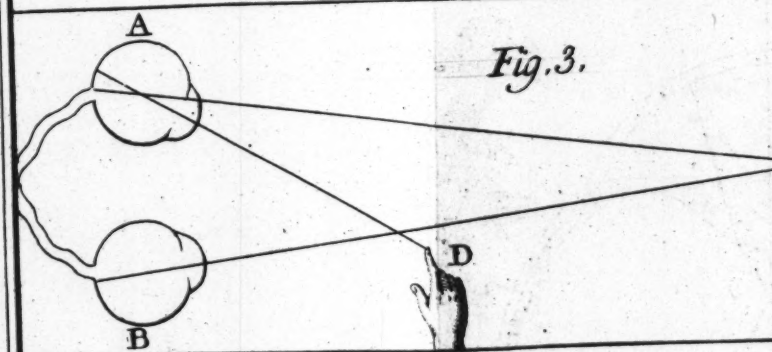
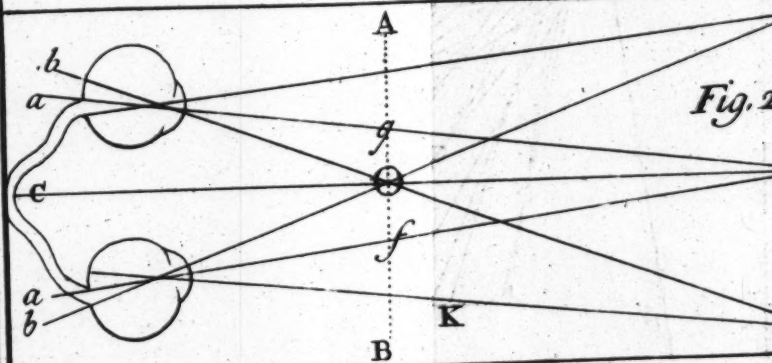
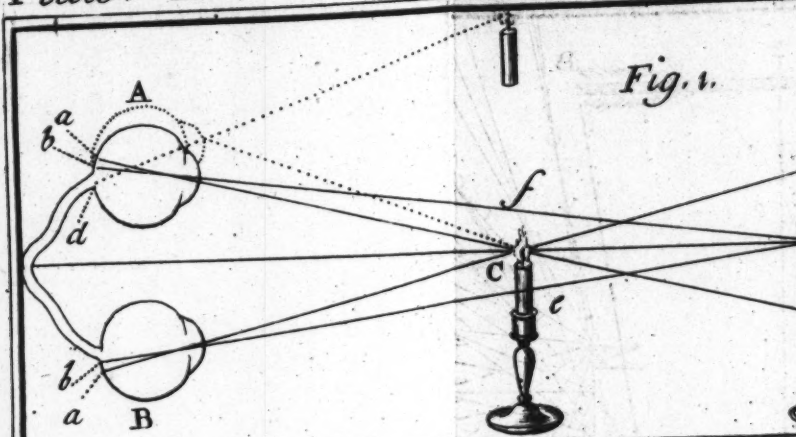
The In piercing the Crystalline Humour, K,
EYE they are still more compact by the same Law.
 In going from the Crystalline Humour, the Rays pass to the vitreous Humour that is a less dense Medium, and there ought to be refracted on receding from the Perpendiculars g, g; but, receding from these Perpendiculars, which have a Direction opposite to the former Directions, the Rays continue to approach one another, and are collected towards the Axis of the Eye, to the Bottom of which they go to convey their Impression, H, I, L. This Impression is made in a reversed Direction. The Ray, A, a, falls in L on the opposite Side, and the Ray, B, b, passes also on the other Side H: because these Rays cross one another conformably to what we see in the Experiment of the dark Chamber. There is only the direct Ray I, K, I, which regularly follows the visual Axis, and is not at all refracted, because it is perpendicular to the Cornea, and to the whole Globe.

Objects are
 inverted at
 the Bot-
 tom of the
 Eye.

If the Experiment of the dark Chamber does not carry with it sufficient convictive Evidence, take the Eye of an Ox, its Bottom stript of the Sclerotis and Choroides in such a Manner, that the nitrous Humour is only covered by the Retina. Place this Eye over against two Candles. You will see those Candles painted in a reversed Order on the Retina, and will observe that the Candle on the right Side falls on the left Side of the Bottom of the Eye. Or,

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If you place one above the other, you will see that the upper Candle will be painted on the lower Part of the Bottom of the Eye, and that the lower Candle will be painted on the upper Part of the same Bottom. A Fact you may easily be convinced of, by removing successively each Candle in order to take an exact Survey of them.

In the mean while, if we place ourselves once more on the Top of *Montmartre*, and take a Prospect of the vast and superb Horizon that surrounds *Paris* and its Suburbs, the astonishing Reduction of seven Leagues of Country to seven Lines at the Bottom of the Eye is but a common Effect, in comparison to what falls out at the Point where all the Rays, that convey

How the Rays of a whole Plain may cross one another without Confusion in the Pupil.

to us this Picture, cross. The Rays that comprise the Picture of all *Paris*, thrice of the Compass of all *Paris*, are united, not in seven Lines, but in a single Point. This is wonderfully surprizing in the first Place. This prodigious Quantity of confused Rays loses, in this supposed Confusion, neither its Direction, nor Colour, nor Force. All these Rays are separated afresh, and approach the Bottom of the Eye as distinctly as if they had never met; an Effect still more astonishing. For, in short, Matter is impenetrable. How therefore can Rays, transmitted from seven square Leagues, keep together in a Point, in a Pin-Hole, thro' which I would see this Plain, and that without being in Contact, without any

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mutual Collision, or the least Interruption to one another imaginable? I own, I do not apprehend it. Because I have no Apprehension but of Things that bear some Resemblance with others I have seen; and it is certain, I could never see even in Light itself a Phenomenon of this kind. It is a Fact, notwithstanding, true, real, and natural; and consequently, tho' I have not an Apprehension of it in the manner I have of large Objects, I can yet conceive it, and form to myself an Idea of it.

It is usual enough to say, that all the Rays of a Plain come to penetrate one's Pupil; and from thence it is surmised, that Light is a penetrable Matter, a Matter that is equivocal. But this seems to me to be a Sort of Imposition. For it is to be remembered, that Bodies do not actually transmit Rays to our Eye, but only excite Vibrations in an Ocean of Light; and that these Vibrations are communicated to the Light that resides in our Eye. A whole Plain therefore does not transmit Rays to the Eye, but a whole Plain communicates its Vibrations to the Light residing in the Eye, in the Pupil. There is ever in my Pupil but the same Quantity of Light, that always answers to the same Cone of exterior Light, from whence it likewise continually receives (the Light being equal) the same Quantity of Vibrations, whether the Cone be small, that is to say, short, as when I am in my Chamber, or whether it has a great Basis, or is long

long, as when I am upon *Montmartre*. All the Difference there is consists in this, that, when I am in my Chamber, my Library, which I have in View, puts the Light in Motion in my Pupil, which all *Paris* would there put in Motion were I on *Montmartre*. Each Volume is, there, instead of a great House, a Palace, or a Church. There would not be more Light in my Pupil on beholding all *Paris*, nor even a greater Motion of the Light that is in it. Only the Parts of Light put in Motion by Books, Pictures, and Tapestry, would be put in Motion by Houses, Castles, and an open Country; that is to say, by Cones of Light corresponding with all these Things. My Pupil, it is true, contains a very small Space of Light to be divided for so great an Extent of Objects. But it is so much the worse in that Respect. For the Extent of Impressions is always the same, and the great Extent of Objects must penetrate the small Extent of my Pupil, and the little Quantity of Light residing there: and if Objects have so great an Extent, or so many Impressions to lodge in this narrow Compass, they will be one upon another, and intirely confused. A House, for instance, will be but a Point of Shade; because it will take up no more Room in my Pupil, than the Point on the Letter i of the Book I read; and from hence arises the Confusion observable in large Prospects. It is therefore evident, that all the Ho-

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riſon of *Paris* does not tranſmit more Light to my Eye, than my Chamber when I am in it, or even the ſole Page of a Book, when I look on it near.

Does not this Precision of Idea, on the Nature of Images, ſeem to begin to render this Effect ſimple and natural? One cannot, it is evident, be under a Temptation any longer of eſteeming it myſterious, or of making it a Subject of divine Revelation. However, let us conſider it with Attention. Tho' I have done all in my Power to render this a ſimple Phœnomenon, and have ſtripped it of its ſeeming to carry with it ſomething miraculous, there ſtill notwithſtanding remains in it ſufficient Matter to fill us with great Aſtoniſhment and Admiration.

The Light of my whole Chamber, or of a whole Plain, does not come to be confuſed in my Pupil; but the Motions imprinted on the Light that is there already, really croſs one another without any Diſorder, which Motions are ever in prodigious Number. Forasmuch as each Toiſe of a Plain, containing one hundred Millions of them, correſponds only with a Point in my Pupil, a hundred Millions of Points of Light muſt ſtill be found in my Pupil, a Circle of a Line and a half Diameter. And theſe hundred Millions of Globules are there at their Eaſe. They have Vibrations that croſs one another without the leaſt Moleſtation; that

that is to say, the Phenomenon of Vision sup-
 poses, that a Circle of a Line and a half, or
 even a Pin-Hole, contains a hundred Millions
 of luminous Globules, besides other Particles of
 Matter of less Subtilty; and farther, that there
 are between these Globules more than a hundred
 Millions of Pores, or a Space larger than these
 Globules, and these other Particles of Matter
 penetrated by them. In a Word, Vision sup-
 poses in matter an astonishing Division, and a
 Porosity more than astonishing; Qualities of
 Bodies the best proved, physical Principles the
 most certain. Does not the Microscope dis-
 cover to us on our Skin five and twenty thou-
 sand Pores in the Space that covers a Grain of
 Sand? A thousand of these Grains of Sand
 might find Room in the Pupil, where would of
 course be contained likewise five and twenty
 Millions of these Pores. But it ought to be
 observed, that these Pores are Orifices of Vessels
 made of solid Sides, composed themselves of
 hollow Tubes, and that these Vessels convey to
 our Atmosphere a Flood of Vapours. It would
 be thought a very extravagant Calculation,
 were I to reckon the Area of this Torrent of
 Vapours, and the Texture of its Canal at a
 Million of Particles. One would meet with
 notwithstanding five and twenty Millions in a
 Space no longer than that of the Pupil. That
 is to say, there would be found two hundred and
 fifty Times a hundred Millions, or two hun-

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dred forty-nine Times more luminous Globules in our Pupil; than I have counted; and in the mean while what a Difference there is between these gross Particles, and those of Light. Must we not then imagine, that there are not above a hundred Millions of luminous Globules in the Pupil, or at least in a Pin-Hole? I have no Inclination meerly to astonish the Reader; for still even this Number, wonderful as it is, ought to be looked upon as falling far short of the real Fact. Nature does not stop there, and we must follow her. Let us therefore boldly pronounce at once, that there are in the Pupil, not a hundred Millions of luminous Globules, but a hundred Millions of luminous Pencils, composed perhaps themselves of as many Globules, and of abundantly more Pores between them. It is obvious thro' all this Work, that the grosser anatomical Observations lead one on insensibly to these most surprizing and almost incomprehensible Finesses of Matter.

Admire then these Phœnomena of Nature, not like one devoted to Mysteries, who redoubles his Enthusiasms in Proportion to their Obscurity, and the impenetrable Darkneſs they are involved in. But be filled with Admiration as a Philosopher, that is touched with the Beauties of the Mechanism which falls under his Conception,

What

What I have been saying, concerning the ^{The} Action of Rays, supposes that, besides the Porosity of Bodies, there is a great deal of Vacuum ^{E. & E.} between the Particles of Matter; and, in my ^{The perfect Plenum of} Opinion, there is nothing in Physics more certain. I will not pronounce with Sir ^{DesCartes,} Isaac ^{and the} Newton, that there is not a cubical Foot of ^{Newtonian com-} Matter from the Sun down to us. But it seems ^{pleat Va-} to me evident, that the perfect Plenum is ^{cuum, are} as equally ^{impossible.} repugnant to the Laws of Nature, as the compleat Vacuum; and that both the one and the other would render Motion impossible: the Plenum by too many Obstacles, as Sir Isaac has demonstrated, the Vacuum for Want of contiguous Bodies, without which there can be no Communication of Motion. Besides, all Matter is porous, and no Matter can be in Contact with another without Vacuities between them. Whatever infinite Series we may suppose of subtile Matter to fill these Pores, the Series of Vacuums will be more than infinite, and follow Matter universally. How willing so ever we may be to unite all these Series of Matter without Intervals, if we suppose them to have a Figure adapted for an exact Conjunction, they would form no more than an universal impenetrable Solid. Gold and the Diamond are only Sponges in Comparison of what would be then the whole Universe. One has not, it is objected, the least Idea of a void Space. In the mean Time it was the first thing I have

The **EYE.** the best Conception of; and I was forced to go thro' a Course of Physicks in order to get rid of this natural Idea, and to be convinced that my Chamber is full of Air. For my Senses had never pointed out to me any thing else than a Vacuum.

As there are Vacuities between the Particles of Light, consequently those Particles are not in immediate Contact, as *Des Cartes* imagined; nor is Light propagated from the Sun to us in an Instant. Because the Vibrations and Undulations of Light run over the small Spaces which divide its Globules, and all Space demands a certain Time to be traversed. Without these Spaces, without these Voids, how can one conceive the Vibrations and Action of Light? But these Spaces are not of that Immenfity as those which Sir *Isaac Newton* makes Light run over, and, on that Account, the Propagation of it is more easily conceived.

The PRINCIPAL PHOENOMENA of VISION.

*Why we see Objects strait, tho' they are
painted reversed in the Eyes.*

THE Soul must see the Rays, or rather must perceive them in the different Parts of the Eye, in the manner she perceives the Fire that affects different Parts of the Hand. If the Fire burns my Thumb or little Finger, she is under no Mistake on that Account. In the mean while the Image of Objects conveyed to the Bottom of the Eye is found reversed from Top to Bottom, from left to right, and yet we cease not to discern the Objects such as they are in themselves. What then in this Case becomes of the Justness of the Soul's Judgment? Or rather by what means will she correct her ordinary Judgment, so as not to render it conformable to the Situation of Images and Impressions, but intirely so to that of Objects? How in short does she convey to the lower Part of the Object, the Sensation she receives at the upper, from the Bottom of the Eye, and to the right the Impression she received from the left?

The

The
Eye.

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The grand Master the Soul follows in this Particular is the Touch. This sole Sensation is the competent Judge, the sovereign Arbitrator of the Situation of Bodies. It is this Master that first told us we walk upright, and that, in consequence of this first Rule, gave us a true Idea of the Situation of other Bodies. The Soul has been convinced by Demonstrations (for such they are) of this Sense, and knows otherwise that the Eyes are very apt to deceive. She therefore said,—Since *Peter*, whom my Hands and the proper Situation of my Body have demonstrated to me to be upright, transmits to the Eye an Image inverted, I will conclude all Objects hereafter to be right, that shall be painted in my Eye reversed, and all those reversed, that shall be painted right. The Judgment of Reason was immediately followed by that of Habitude, and, Habitude once established, it is a kind of *Ænigma* to divine the manner after which the Soul can see, that is to say, judge Objects right, tho' they are reversed in the Eye.

But why, you will ask, do not those that are born blind, on acquiring their Sight, at first see Objects reversed * ?—These blind have all their
Lives

* It is no where demonstrated, that these Novices in the Art of seeing saw not at first the Objects reversed. On the contrary, we have already proved, that they must have been apprized of this Inversion. But supposing there have occurred some, who have judged Objects upright on the first Use they have made of their Eyes, see how that may be very rationally accounted for.

Lives felt the Objects, and formed an assured Judgment of their Situation. Their Soul therefore is not so liable to a Misapprehension as those of others are. Nay, it is possible the reversed Sensation may make a Part of the Astonishment they are seized with, on the breaking in of Light; and that in the Crowd of Images, they have no distinct Perception of this Singularity. But this Inversion of Objects has no Effect on their Ideas, so well established by the long Lessons of their true Master, the Touch. The old blind Man, Fig. 3, Plate IX. accustomed to conduct himself along with his two Sticks, and to judge by means of those of the Situation of Bodies, is not at all deceived in that Respect. He knows very well that his Dog, which he touches with his right Stick, is on the left, and that the Tree, touched by his left Stick, is on the right Hand. Should he in an Instant be accommodated with two good Eyes, at the Bottom of which the Dog would be on the right, and the Tree on the left, he would suspend his Belief, and refer the Matter to the Demonstration of his Sticks, which he is convinced are infallible.

The Soul makes as much of it, at least in regard of all Objects, on which the Experience of the Touch has been able to shed its Lights, either immediately, or by Comparison. I have my Reasons for adding this Restriction. The Principles we have been taking a View of, conducted

The **SIGHT** conducted me to surmize, that the Soul saw sometimes Objects reversed, thro' want of the Means just mentioned. And, in short, I have been happy enough to be convinced of this by an Experiment as singular, as simple; with which one has the additional Advantage of demonstrating the Inversion of Images in the very Eyes of any one that makes the Observation. And here it is,

Place a Light at a moderate Distance from a smooth and very convex Body, in such a manner that a small luminous Point of it may be determined towards yourself. In order to succeed with more Certainty, prevent the first Light from falling on your Eyes. Shut afterwards one Eye, and look at the luminous Point in an indistinct manner, that is to say with the Eye relaxed or dilated. This Point will appear to you larger and beamy. Then if you put your Finger on the right Side of the Eye that is open, and move it towards the Axis of this Eye from right to left in order to cover this luminous Point, you will distinctly find the Shade of your Finger come on the contrary from left to right, and pass over the luminous Point in a Direction opposite to that you gave it. If you afterwards make your Finger pass before the luminous Point from left to right, its Shade will pass there from right to left. In short, if you make it pass from high to low, or from low to high, its Shade will still pass in a contrary

contrary Direction over the luminous Point. It is therefore plain, that the Soul sees at first the Objects inverted in the manner their Images are in the Eye; and that she determines the Impressions to the Places of the Eye, where she perceives them, and not to the Places from whence the Rays come, as she does when she can rectify her Judgment. For here she sees my Finger go from left to right, when it goes in reality from right to left. The Soul therefore at that Time concludes the Impressions reversed as she perceives them, and consequently does not correct her Judgment. And from whence does this proceed? The Reason of it undoubtedly is, because this luminous Point has neither high, nor low, nor right, nor left, nor any glaring near Object, to awaken and fix the Attention of the Soul. In a Word, there is nothing that can determine her Judgment.

I have farther tried this Experiment on several large Bodies moderately enlightened; but this is what strikes one most, and of course must be deemed sufficient.

How we discern a single Object, tho' its Image makes an Impression on both Eyes. And why we see sometimes double.

THIS is another wonderful Phenomenon, founded on our Ignorance of the manner the Soul is affected in by the Images of Objects.

When

The
SIGHT.

When we look upon an Object, each of our Eyes receives an Image of this Object. There are therefore two Images making at one Time an Impression on our Soul, when in the mean while we discern but a single Object.

In case the Soul left one of the Eyes in a State of Inaction, and made use only of one Eye at a Time, or were attentive but to one of the two Images; the Difficulty would soon be solved, which, indeed, is the ordinary Conduct of the Soul. To be convinced of this Point, look with both Eyes, A, B, Fig. 1. Plate X, at the Candle C. Beyond this Candle have two Objects fixed, E, F. Look at the Candle with a strong Attention; and see with which of the two Objects, E or F, corresponds. If with the Object E, it is with the right Eye you discern this Candle. If it corresponds with the Object F, you see it with the left; or at least your Soul is only attentive to the Image painted in one of your Eyes; and this manner of seeing is the most general. We do not observe an Object attentively but with the Eye that is next it, or more within its Reach; while the other Eye is in a Sort of Repose, until its Turn comes to let the other rest. I have myself observed, that there are certain Days, when it is almost ever the Turn of a particular Eye solely to see the Objects that present themselves. And I have had room to conjecture, that this was owing to that Eye's
having

having on these Days more Vigour than the other. I am perswaded, that, in regard of a Number of People, one Eye is ever stronger or more on the watch, than the other, and constantly takes upon itself the greatest Share of the common Talk.

For Instance, *Borelli* asserts, that the left Eye is stronger, and always discerns more distinctly, than the right*. I have verified this Observation by Trials on several Persons: but I have discovered likewise that it is not a general one. There are Eyes perfectly equal, such amongst others are my own. There are, on the contrary, Instances, where the right Eye is the most vigorous. Were *Borelli's* Observation invariable, and universally true, I would declare without Hesitation, that the right optic Nerve is less supplied with Spirits, and has less Force; by reason that the right Arm, being more active and more employed than any other Part, has a greater Quantity of Spirits flowing thro' its Nerves; and that this great Expence of Spirits is borrowed of the Nerves of the same Side: and that, on this Account, the right optic Nerve, furnishing a good Part of this Contribution, is so much the more impoverished. The same Reason is assignable for the extraordinary Supply of one of the Organs in the male kind subservient to the perpetuating the Species.

Tho'

* Journal des Sçavans, 1673.

Tho' this Sort of one-eyed Vision I have been speaking of, be usual, it is far nevertheless from being universal, as some imagine; and, consequently, cannot resolve the Phenomenon in Question.

The first Time I was convinced that I saw the same Object with both Eyes at once, I lay in Bed on my left Side, both my Eyes determined vertically, as in Fig. 4. Pl. X. had my Body and Feet extended towards Q; over against me was a Window A; and between me and the Window there was the Back of a Chair B. The Back of this Chair hid from me all the lower Part C D of the Window. I looked at the Window and the Chair in a confused manner, that is to say, as one does ordinarily on waking. I saw all the upper Part A C of this Window, but on the lower, C E, I distinguished a Crowd of Vapours e, e, of the Figure of the Back of the Chair.

On leaving only the right Eye, a, open, I saw this Window A C intirely, without any Part of the Body of Vapours. But, on opening only the left Eye, b, I discerned no more of the Window than the Space A E; that is to say, all that was above the Place where ascended these Vapours. — Consequently, there was only this Portion A E, that was within Reach of being seen with both Eyes at once; the Part E C being hid from the left Eye, b, by the back of the Chair B. It is for this Reason, that, on

looking

looking with both Eyes, I saw the Part A E more distinct and more luminous, because I saw it with both Eyes at once, its Situation being above the Axis, b, e, of the Eye below, and, consequently, within reach of imprinting its Image on both Eyes.

The Portion E C appeared less distinct, or covered with a vapourish Column; because this Portion, being situated above the Axis, b, e, of the left Eye, b, was hid from this Eye, and so was seen only by the right Eye, a, which being higher than the left Eye, sunk its Axis, a, e, above the Chair, to the lower Part, c, c, of the Window. Now this Part E C was seen only by one Eye, and, consequently, affecting but a single Organ, imprinted a less Sensation in the Soul. From hence arose that feebler Vision, or the Collection of Vapours, with which the Object appeared covered.

From this Experiment I conclude, first, that we see Objects with both Eyes at once.

Secondly, that one sees better with both Eyes than with one. Because the Portion A E, discerned by both Eyes, always appeared to me clearer and more luminous.

Thirdly, that one sees better on looking with Attention, with a Sort of Effort; as one carries a Burthen better on exerting one's self, than when one marches languidly under the Weight.

O

Fourthly,

A Physical Essay

Fourthly, that, in case we sometimes see the Object but with one Eye, it is because the Attention is excited rather in this Eye, than in the other, by reason that the Object is on the Side of this Eye, and first strikes it; or else, because we have acquired a particular Habit of putting this Eye on Action rather than the other.

Let us recur to another Experiment of the same kind, which will conduct us a little farther into the Mysteries of Vision.

Put upon the same Line two Candles, C D, Fig. 1. Pl. X. Look with both Eyes AB, and with a strong Attention, on the first Candle C, you will find it, as formerly, but one Candle, tho' the Candle C transmits an Image to each Eye, A, B. But, if you look at the Candle C, as if you were confused, that is to say, dividing a little your Attention, between this Sensation and the others your Eyes may receive, then you will see at the same Time the Candle at a Distance D; but you will see it confusedly and double; that is to say, one in f, and the other in e, on each Side of the first Candle C.

In like manner, if you look earnestly at the second Candle D, you will see it single. But, if you look upon it with a Sort of Distraction, you will see on its Sides E F, the first Candle, C, double and confused. It is necessary to look at it like one confused, to see this Duplicity, by reason that from the strong Attention,

tion, one sees only with one Eye, or is solely attentive to the Image painted in one of the Eyes, as has been above observed. The SIGHT.

Let us remark, before we explain this second Experiment, that when one looks upon an Object with both Eyes, these Organs are turned towards the Object in such a manner, that it becomes placed at the Extremity of the Axis of each Eye, and the Centre of each Image is painted on the Choroides of each Eye, at the Point that corresponds with this Axis.

This being supposed, it follows from the preceding Experiment, that every Time both the Images fell on the Points of the Choroides, which correspond with the Axis of each Eye, these Images are confounded in a single one. But when both Images fall wide of these Points, whether inwardly, or outwardly, above or below them, these Images are no longer confounded one with the other, but one sees them both, and the Object appears double.

For Example, when you look at the Candle C, you turn both Eyes towards it so that it is found at the Top of the Angle made by the Union of the Axes of both Eyes, and the Images fall both of them on the visual Pole, a, a, of each Eye. In this Situation of the Eyes, the Images of the Candle D fall in b, b, outwards, and on this Side of the visual Pole; and on this Account these two Images are

The perceived separately, and the Candle appears
 SIGHT. double.

For the same Reason, if you look on the Candle D, while the visual Pole is b, b, the Images of the first Candle C will still be seen double; because they fall in a, a, out of the Poles of Vision: which is the Reason why drunken People see Objects double. Because their Eyes being half paralytic, as well as their Limbs, are fixed, as it were, and immoveable. They do not direct in an exact manner the visual Axes towards Objects; so that the Images of these Objects fall out of the visual Pole, and, consequently produce a double Vision.

An Object is farther rendered double, when, on looking on it with both Eyes, one forces an Eye with a Finger either upwards, or downwards, or sideways. Hence the Image is dislodged from the visual Pole, where it was before, and this Image is seen separately.

This second Object, at the same Time, seems to change Place, and to recede from the former. For, on pushing the Eye aside, you make the Rays, which go from the Eye, pointed, A, Fig. 1, fall obliquely on this Eye, and refract themselves besides in piercing it. Now, as the Soul ever conveys the Impression of Images in a direct Line, d, h, or to the Extremity of the Axis, d, in Contact with the Organ, or the Bottom of the Eye; it follows, that the second Object ought to appear in h, at a sufficient

ficient Distance from C, which is the real Object.

The
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The Soul always conveys the Impression of Images in a direct Line, because she does not see the Object in the Place where it is. She sees it in the Eye itself : For her Affair is with the Image, not with the Object. Now, from whatever Point the Image comes, after it has pierced the Cornea, the aqueous Humour, and the Crystalline, it is refracted for the last Time in the vitreous Humour ; where it describes a strait Line to the Bottom of the Eye. And it is according to this last strait Line lengthened, d, h, the Soul sees the Object, as if it were on the Eye itself. A Person, unaccustomed to look at Objects thro' a perspective-Glass, would see them in the Glass itself. And I have known, when there has been no perswading some particular People, that the Star I shewed them in the Glass, was the same I made them see in the Firmament without it. Any one, arrived at the Use of Reason the first Time of his Life he saw, would likewise declare the Objects were actually in his Eyes. He would conclude, what we only discover by the Force of reasoning ; to wit, that Vision is a kind of Sensation of the Touch, and would imagine he even felt the Objects on his Eyes. This is what is confirmed by the History of one born blind, which we shall relate in the Sequel of this Treatise. One may be therefore assured, that

The
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Infants see in this manner, and that it is in us an Art, a Science, acquired by a Habit of judging that Objects are external in our Regard, and at a certain Distance.

I was saying, that an Object discerned with both Eyes appeared single, when each Image falls directly on the Point of the visual Axis, or on the Pole of each Eye; and that appears double, every Time the Image falls wide of these Points.

Let us make some farther Experiments, before we examine what this Point of the Axis, this optic Pole, is.

Place two Candles, E, F, Fig. 2, Pl. X. at a certain Distance one from the other. You are in C. Look at these Candles thro' a Hole, o, made in a Board, or a Pasteboard A, B, and you will see both Candles, but you will see two Holes, one for each Candle, tho' there be but one Hole for both. The Reason of it is, because when you look at both Candles E, F, the Axes of both Eyes a, G, a, are directed to the Height G, which is the common Point in this Distance. In this Direction of the Eye, the Image of the Hole, o, falls obliquely, o, b, on each Eye, and out of the optic Pole. Therefore the Hole must appear double, and each Hole has its Candle, because the Candle, E, falls just by the Hole, o, upon the right Eye in E, and likewise out of the optic Pole; the Candle F falls by the same Hole, o, on the left

left Eye, still in b, out of the optic Axis. There is only the Point G which falls upon the Axis, a, a; and as the Soul reports the Situation of Objects according to this Axis, the two seeming Holes, with their Candles, appear in f, g, on the Side of the true Hole.

In the mean while, if you look earnestly at the real Hole, o, the Line b, o, becomes the optic Axis; so that you will see only one Hole and one Candle, tho' there be two Candles. You will see but one Hole, because it is at the Top, o, of the Optic Cone, b, o, b. You will see but one Candle made of both, because both Images are actually confounded at this Top of the optic Cone in passing by the Hole, o, and fall as well as the Hole upon the visual Axis, o, a. Now Objects, it is to be remembered, whose Images fall in this Axis, always appear single, altho' they have an Image in each Eye.

It is true, that the single Candle which you see on looking steadily on the Hole, is composed of both: and that if you put your Hand before one of the two Candles, you see that which is before your Hand, and see besides the Transparency which that, which is behind, produces across your Fingers. Or else, if you put a yellow Glass before one of the Candles, and a blue Glass before the other, the single Candle which you see will be green; that is to say,

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composed of the yellow of the first Candle, and the blue of the second.

Instead of looking thro' the Board, A, B, place at the Hole of it the pierced PASTEBOARD, x. Look thro' this new Hole at both Candles, E, F, you will see two Candles and two Holes as in the preceding Experiment. But, on looking earnestly at this Hole, o, of the PASTEBOARD, instead of seeing only a single Candle, you will see three of them; to wit, the Candle composed of the two that pass thro' the Hole, o, as in the first Experiment, and moreover the Images a little confused of each Candle E, F, that will pass on the side of the PASTEBOARD by the Lines F, K, and E, K; Images that were before intercepted by the Board A, B.

If you examine the Eyes of whoever makes the preceding Experiments, you will observe that when he looks earnestly at the Hole, o, his Eyes are approached one to the other according to the Angle b, o, b; and that when he looks at the Candles E, F, thro' the same Hole, his Eyes, or rather his Pupils, are visibly wide of each other, and placed in the Directions of the Angle a, G, a. So that the Explication is verified even by ocular Inspection.

If instead of looking with both Eyes, one looks only with one, then this Eye does not change the Direction, whether one looks at the Hole, or at one of the Candles; so that one

never

never sees more than one Hole and one Candle. The
 Consequently, the Phenomena I have been ob- SIGHT.
 serving depend on this; that, on looking with
 both Eyes, each Eye assists, by reason its Di-
 rection concurs in the common Axis, C, G:
 for Example, the right Eye singly would be
 directed in b, E, the left Eye singly in b, F.
 But when they see together, their Direction
 takes a common Medium G, and from thence
 proceed the foregoing Mistakes.

To omit nothing, farther desirable, in regard
 of these Phenomena, it is necessary to deter-
 mine the optic Poles, those Points of the com-
 mon Axis, where Objects appear single, and
 out of which they appear double, and to assign
 the Reasons for these Appearances.

The optic Axis was heretofore imagined to
 be the Center of the optic Nerve. These two
 Nerves were said to cross one another, and on
 that Score the Impressions which fell on both
 these Nerves, being conveyed along their
 Tubes, were supposed to meet in a single Point
 at the crossing of these Tubes, and to be there
 confounded together.

We have seen above, that the Centre of the
 optic Nerve is incapable of this Function.
 But, tho' it were capable of it, this crossing is
 imaginary.

Some of the Moderns, apprised of these Diffi-
 culties, have fixed the optic Axis on the Point
 x, Fig. 4. Pl. X. of the Choroides, or of the

pia

The
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pia Mater, which is on the inner Border of the Insertion of the optic Nerve; and say, that these Portions of the *pia Mater*, uniting before the Concourse, y, of the two optic Nerves, exactly where the common Axis, y, t, corresponds, both Impressions must necessarily be resolved into one.

These Gentlemen do not succeed a Jot more happily than the former. First, it is a Fact proved by the most exact Anatomy of the Eye, and by the Experiment of M. Mariotte, see p. 154, &c. that the Axis of the Globe of the Eye, or visual Axis, falls on the Outside of the optic Nerve, as it is represented in all our Figures. Secondly, the Sensation is made in the Organ itself that is affected. The Prick of a Pin upon the Finger affects the Finger. A Ragout that one tastes, affects the Tongue; and, consequently, Light affects the Eye, and not the Origin of its Nerves, as we have seen in the general System of Sensations. Thirdly, by supposing but one Point in the Bottom of each Eye, where the Impressions are united; would this simple Point suffice to give us a single Image of an intire Country that fills the whole Bottom of our Eye? By admitting a Point of this Nature, there would in-like manner be but one Point of this Country, where we should see single Objects, all the rest of the Country would be double, by reason it would not fall on this Point.

The

The optic Pole is not a Point. What is it then? It is the whole Bottom of the Eye that has the optic Axis for its Center. Now every Image, whose Center corresponds with that of this Pole, represents to us a single Object, altho' the Image be in each Eye; for the same Reason that we hear, with both Ears, a single Sound, tho' it makes a double Impression. It is not because the Sensations are confounded by the Re-union of the Motion; which is a Chimera, and really found to be such, in both those Ears, whose Nerves and Organs are very different. It is the Mind herself that makes this Re-union by a Judgment she acquires by Habit and Experience. She knows that a single Object is that which occupies one Place only proportioned to its Circumference; and that a double Object is what occupies a double Space, or is in two different Places. So that when there arrives an Image in each Eye, both which Images are carried in a strait Line to the same Point, the same Place, and are precisely the same in their Position and Form, inasmuch as the Object is in the Axis common to both Eyes, and occupies the same Place, the same optic Pole, and affects the same Parts in each Eye; then it is the same Sensation proceeding from the same Quarter; so that we consider this double Image as a single Object: for we perceive and see but one Object.

If

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If an Eye is turned out of the common Axis, the Direction of the Image is changed, and the Object appears double, as we see Plate IX. Fig. 1. at the Eye that is pointed; because, in that Case, you fancy this Image in a different Place, *h*, to that *C*, from whence the Image arrives, and from whence it is received by the other Eye, *B*. Now each Image being carried to two different Places, *C*, *h*, we imagine the Object double, because it appears to occupy two Places.

How
squint-
eyed Per-
sons see.

One that is squint-eyed, however, looks at Objects with both Eyes transversely, without seeing them double. It is true. But a squint-eyed Person, without being conscious of it, ever sees but with one Eye, tho' he imagines he looks with both. I lately unfolded this Doctrine to one that squinted very much with his left Eye, who at the same Time firmly believed he saw with both Eyes at once. I assured him that he only saw with his right Eye, and it was thus I convinced him.

I made him look with both Eyes, A, B, Pl. X. Fig. 3. at the Object C. I observed his Eyes while he looked at the Object; and the better to distinguish the Direction of them, I had likewise remarked those of a Person whose Eyes were right. I saw then that the sound right Eye, B, of the squinting Person, was actually turned towards the Object; but that

that the other Eye A, at the same Time was turned towards D. The
SIGHT.

It may be objected, that it was perhaps in this Direction A, D, that the squinting Eye saw the Object, C. But in order to obviate this, I put my Finger at D, where the left Eye was directed, when the Person said he looked with both Eyes at the Object C, and the Instant he looked thus at the Object C, I shut his sound Eye, and begged him to look at my Finger, D, with his squinting Eye, A. He looked, and saw my Finger, without the squinting Eye's changing the Direction A, D, which it had when he said he looked with both Eyes at the Object C. I desired him afterwards to look on the Object C with the left Eye; and then this squinting Eye, looking singly, was turned towards the Object C, as exactly as the sound Eye B had done before: From whence it follows,

First, that the optic or visual Pole of a squinting Eye, is the same as that of a straight Eye: since, when it acts solely, and really sees an Object, it turns its Axis upon this Object, as the straightest Eyes do.

Secondly, that when one who squints, views an Object with both Eyes, he sees it, in the mean while, only with the sound Eye: inasmuch as the other is directed every where but on the Object; and, as it is evident by the foregoing Proposition, that, on looking at an Object,

The Object, he directs his Axis towards this Object. It is no astonishing Circumstance, that a squinting Person sees but with one Eye; since, as we have proved above, generally speaking, those that have Eyes the straightest and best directed towards Objects, see them, notwithstanding, but with one Eye: because ordinarily the Imagination attends only to that of the two Images, which makes the stronger Impression; and therefore sees solely with the Eye that is strongest and quickest. Now a squinting Eye is vitiated, feeble, unactive, and consequently is ever idle when the other is on Duty. But when the sound Eye is shut, then all the Spirits, all the Efforts of Attention, are determined to the squinting Eye. These Efforts put it in an Equilibrium on its Axis, direct it towards Objects, and then the Eye no longer squints, but sees. It is by this Management, that the Eyes of Children are sometimes cured, by closing their sound Eye, and forcing by that means the squinting one to rectify itself. We have seen here a famous Quack * abuse this Mechanism, in order to impose upon the Public, and even the most intelligent Part of them.

In making the Experiments I have been mentioning, a Person was found out, who had the Knack of mimicking one that squinted. But this voluntary Squinter saw Objects double,

because

* TAYLOR.

because his Eye, tho' turned from the common Axis was sound, and active, and no Ways impaired, thro' Inactivity and Want of Use: so his Case was like that of those, who push an Eye aside with their Finger.

It is by this same Explication we account for the following Observation. A Person became squint-eyed from a sudden Accident, and at first saw Objects double. But in Process of Time, tho' his Squinting continued, he saw them single, as before he grew squint-eyed. It seems to me evident, that this squinting Eye was, in the Beginning, still sound, vigorous, and in the State of the Eye of our voluntary Squinter, which was the Reason why he saw double. But at length this Eye, either thro' the Illness that had occasioned this Defect, or thro' Inactivity, lost by Degrees the Faculty of seeing, which now depended wholly upon the good Eye, and then the Person began to see Objects single.

In the mean while, in case there be a Squinter in the World, that sees an Object with both Eyes at once without seeing it double, the optic Pole of his squinting Eye must have never been in the Axis of the Globe of the Eye, whether thro' a Defect in its Construction, or thro' Habit, if Habit can even here avail any thing; or else this Eye, from the Refraction made in it being different from the ordinary one, must have been obliged to throw itself towards

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SIGHT.

wards one particular Side, in order to make the Image fall upon the optic Axis, which afterwards grew into a Habit. Refraction in an Eye may be likewise disconcerted thro' the displacing of the Crystalline Humour, the irregular Formation of the Eye itself, &c.

But both in one and the other Circumstance, should such squinting Persons look at an Object, the good Eye being shut, the other would not at all rectify itself, as it does in all other Cases. It would look a-squint being single, as if it were with its Fellow: since, in the first case, the optic Axis is supposed to be a-skew, and in the other, where Refraction is disconcerted, the Image can no ways fall upon the optic Axis, tho' strait; nor is the Eye turned a-slant to catch the Point, where this disconcerted Refraction conveys the Image upon the optic Axis.

From all this we conclude, that the *optic Pole* is that Region of the Bottom of each Eye which is in Sympathy with the other, and whose Center, called the *optic Axis*, ordinarily the Axis of the Globe itself, is directed to and united with the common Axis, when both Eyes actually look at an Object; that every Time this Union is made, the Image of the Object, tho' double, one in each Eye, causes us to see but a single Object, because both Images are conveyed to one and the same Place; and that out of this common Axis the Object appears double,

double, because each Axis of the Eye, and consequently each Image, is transmitted to ^{The} Places different one from the other, and that ^{SIGHT.} thus the Image of the same Object corresponds with two different Places.

How we judge by the SIGHT, of the Magnitude and Distance of OBJECTS.

EFFECTS of Glasses, and polished Surfaces, plane, convex, and concave.

THE Mind not only rectifies the Image of Objects which occurs reversed in the Bottom of the Eye; it not only simplifies the double Impression of these Images in a sole and single Sensation; but judges, moreover, of the Distance and Magnitude of the Objects it discerns. What means does it make subservient to this third Operation?

The first of these means is the Magnitude of the Image itself, transmitted to the Bottom of the Eye; or, as we say, the Magnitude of the *visual Angle*. There can be nothing more simple and more natural, than this first Expedient by which the Mind judges of the Magnitude of an Object, by the Magnitude of its identical Image.

We have seen that the Rays cross one another at their Entrance into the Eye. Now the nearer the Object, from whence these Rays are transmitted, is to the Eye, the more considerable

First Rule
is the Magnitude of the Image itself in the Bottom of the Eye.

The nearer the Object, the larger is the Image, in Proportion.

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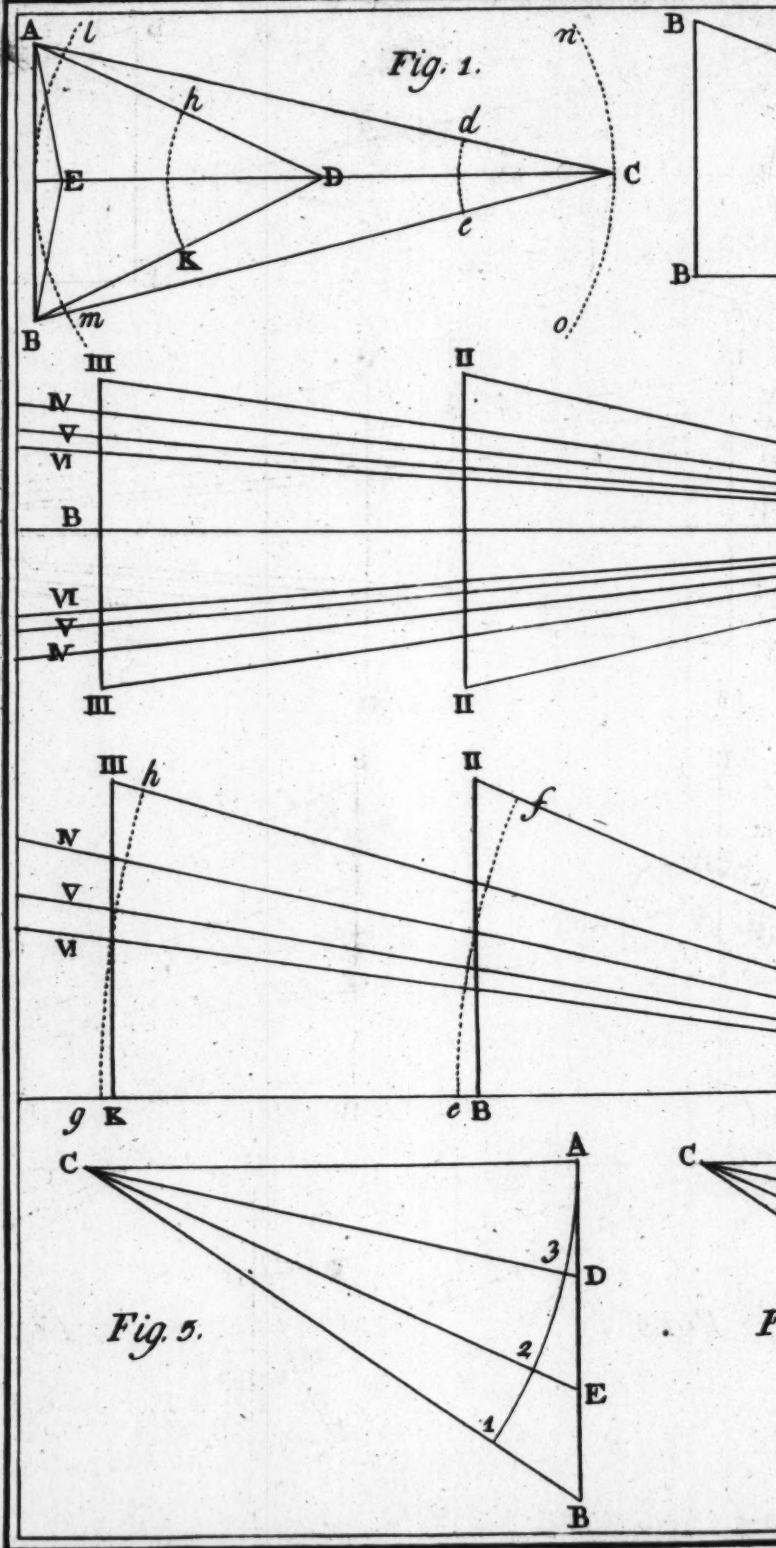
able is the Angle formed by this crossing. For Example, if one looks at two small Statues of the same Magnitude, 1, 6, Pl. XII. Fig. 1. one at the Distance of a Foot, the other of six Feet; the Statue placed at a Foot's Distance will appear to us almost six Times larger than the Statue placed at the Distance of six Feet because the Opening bc of the visual Angle of the first Statue, 1, or the Height of its Image is near six times as large again as the Opening ef of the visual Angle of the second Statue, 6. It is upon this Principle that all Perspective is founded.

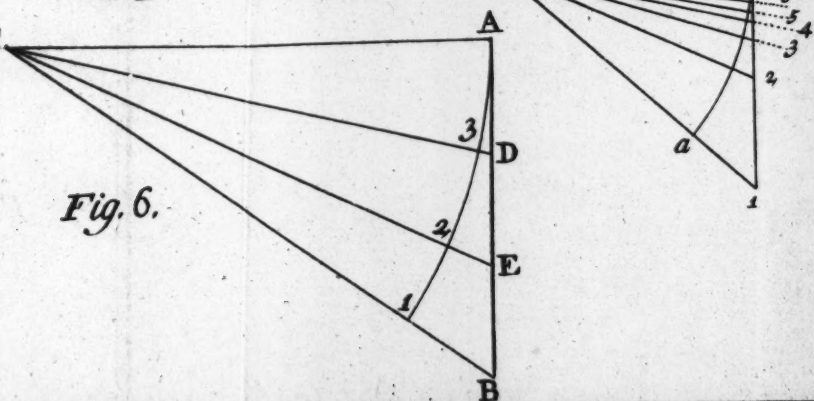
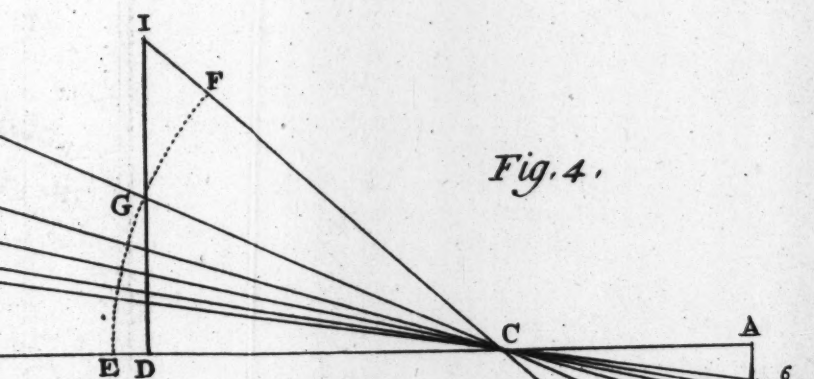
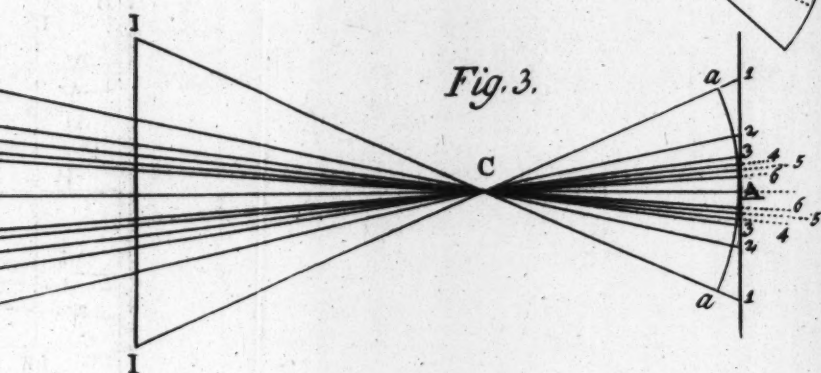
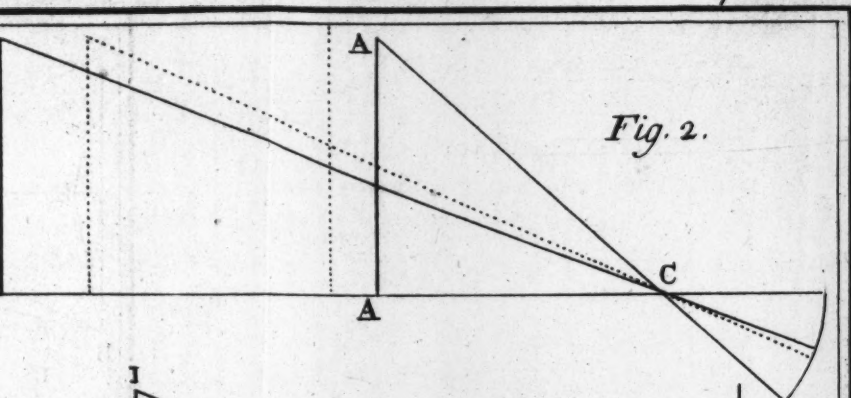
An Object viewed near, forms in the Eye a larger Angle, because the Base of an optic Triangle, which is the Object itself, being nearer the Eye, the Triangle becomes shorter, and the Angle on the Top is rendered so much the larger. If the Object A, B, Pl. XI. Fig. 1. is seen from the distant Point C, the optic Triangle is ACB . If you view it afterwards nearer as from D, you have then for the optic Triangle ADB comprised in the former Triangle, and obtaining the same Base as that. Now the smaller or shorter is the contained Triangle so much larger will its Angle D be in Proportion, than the Angle C*. So far, that the contained Triangle is extremely short, AEB , the Angle E will be so obtuse, or so large, that both its Sides AE , BE , will form almost

* Euclid, B. I. Prop. 21.

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almost a strait Line; and in case one conceives ^{The} the Triangle infinitely shorter, the Difference of ^{SIGHT.} the Angle E, with the strait Line AB, will be infinitely small. Therefore the nearer the Object is, which we survey, the larger must be its optic Angle. The Triangle, we have been speaking of, is the optic Triangle situated between the Object and the Pupil, or, it is the outer optic Triangle. By the crossing of the Rays in the Pupil, there is formed in the Eye a Triangle proportioned to the former. It has its Base at the Bottom of the Eye, and its Top opposite to the Top of the exterior Triangle. Consequently, these Angles of the Tops are equal, and the Sides of each Triangle are proportional, and the Bases themselves are in Proportion. The larger the top Angles are, the larger these are.

But why does not an Object at twice the Distance, form an Image as small again, and an Object six times as far off, an Image six times smaller? The Reason is, because it is demonstrative by Geometry, that the great Angle D, which is as near again to the Base AB, as the small Angle C, is not in the mean while as large again as this small Angle C, but falls somewhat short of it. For the Arch h K, double the Arch d, e, the Measure of the Angle C, is larger than is requisite to measure the Angle D. There is a small Overplus; and supposing there had been none at all, and that

The Magnitude of the Image not exactly proportioned to the Distance of the Object from the Eye, but wants a little of it.

The
SIGHT.

the Angle A D B were exactly double the Angle A C B, the Sides of these Angles must have terminated in the Points l, m ; because in that case both those Angles would be comprised in the same Circle ; the more acute Angle C would be in the Circumference of this Circle, the less acute Angle D would be in the Center of the same Circle, and both of them would have for a Base the same Arch, l, m, of the Circle, Portions of which are exhibited in the Figure at l, m, n, o. From whence it follows in Geometry, that this latter Angle D would be double the other Angle C *. But as the Angle D is not wide enough to fall in with the Sides of the Angle C at the Points l, m, it follows that it is not large enough to be double the Angle C. Consequently, the Image seen as near again (D) will not be intirely as large again ; and for the same Reason the Image seen at twice the Distance C will not be exactly as small again, according to these Geometrical Laws.

Let us examine these Proportions in another Point of View more immediately connected with the Matter in Hand. The real Magnitude of Objects is ordinarily an upright Line and perpendicular to the Horizon, I, D, Fig. 4 ; whereas the Measure, and consequently the Magnitude of the optic Angle is the Arch, on the Curve E, F. Now Geometricians demonstrate, that this Curve E F is less than the upright

* Euclid, B. III. Prop. 20.

right Line ID ; and that thus the apparent Magnitude of Objects, or their Image, is less than their real. They demonstrate farther, that this Curve EF , which is less than the upright Line ID , is also in a less Ratio with its Distance DC , than ef is with the Distance BC ; that is to say, the Curve or the Image EF of the neighbouring Object is not so large, in regard of the Distance DC , as the Curve or the Image, ef , of the distant Object, is in respect of its Distance BC . For it is evident, that the nearer the same Object is to us, the wider is the Angle, and the shorter the Arch EF formed at the Center C ; and the more it contracts, likewise, the Base of the optic Angle, and the Image this Base transmits, The sole Inspection of the Figure may convince any one, that the Arch fe , which is at the second Distance, is less curved than the Arch EF ; and that it diminishes so much the less of the real Magnitude of the Object; and that the Arch gh , which is at the third Distance, does so still less than ef , and so on. On which Account the nearer an Object is, the more its Image suffers from this Sort of Abatement, which hinders the Magnitude of this Image from corresponding exactly with the Proximity of the Object.

The Rays cross one another in the Eye, as at the Point C , and there form Angles almost equal to the exterior Angles. I say almost, be-

The
SIGHT.

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cause Refraction in assembling the Rays, still straitens, in a small Degree, the Base of these inner Angles. The Eye is spherical. Therefore the interior optic Angle is measured and bounded by a Curve A a, which reduces the Images, as well as, it is evident, the exterior Angles are. This inner Curve is the essential one. It is that which measures the Extent of the Impression, and gives the Form and the Magnitude to the Image. It is this Curve that cuts off the Portions k b, h c, of the large Image b c of the Statue i, Fig. 1. Pl. XII. and retrenches nothing or scarce any thing of the small Image, e f, of the Statue 6. It is this same Curve of the Eye, that so much abridges the large Angles of the Figures 3, 4, Pl. XI. and hinders besides their Images from being proportioned to the Proximity of Objects; whilst it shortens very little, or nothing at all, the strait Angles, or the Angles of distant Objects, and on that Score causes a less Diminution of their Images, than of those of nearer Objects. From whence the Images of distant Objects are larger, considering their Distance, than the Images of neighbouring Objects are in regard of their Proximity.

One will remark therefore in these Figures, on measuring the optic Angles, by the Curve which describes the Bottom of the Eye, that the Object. II. Fig. 4. that is but as far again as the Object I. transmits to the Eye an Image

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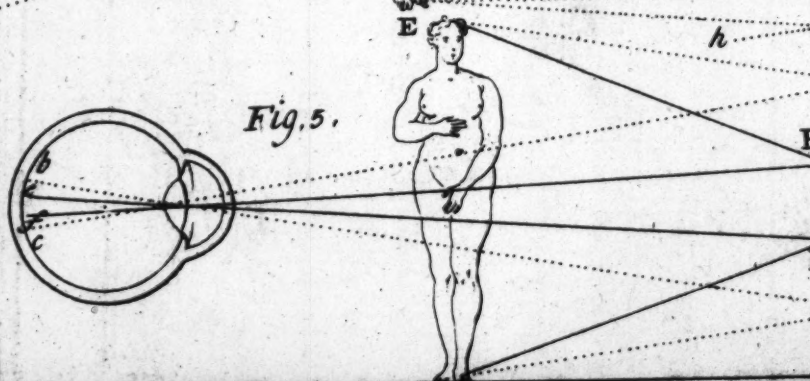
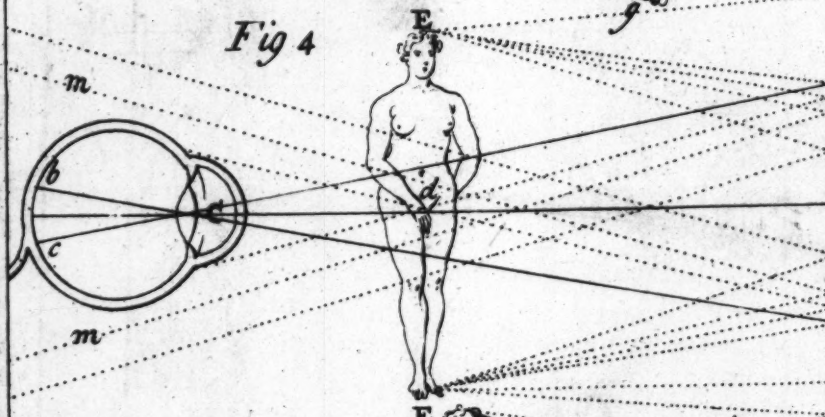
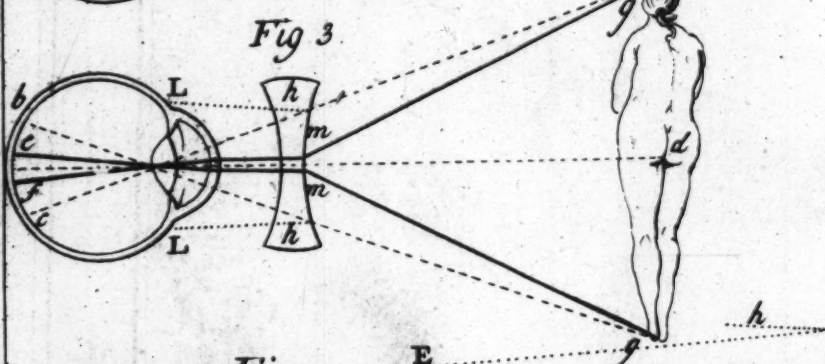
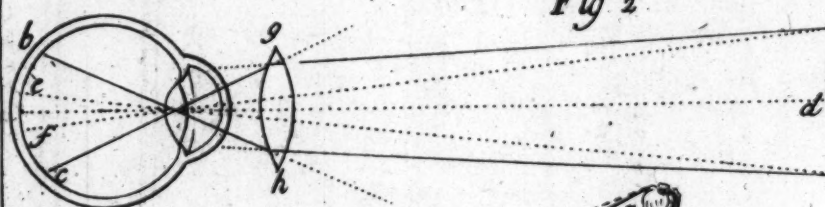
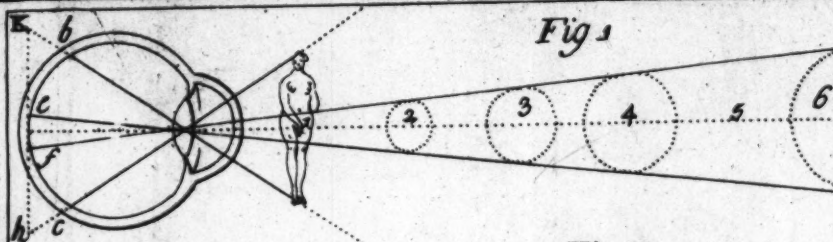
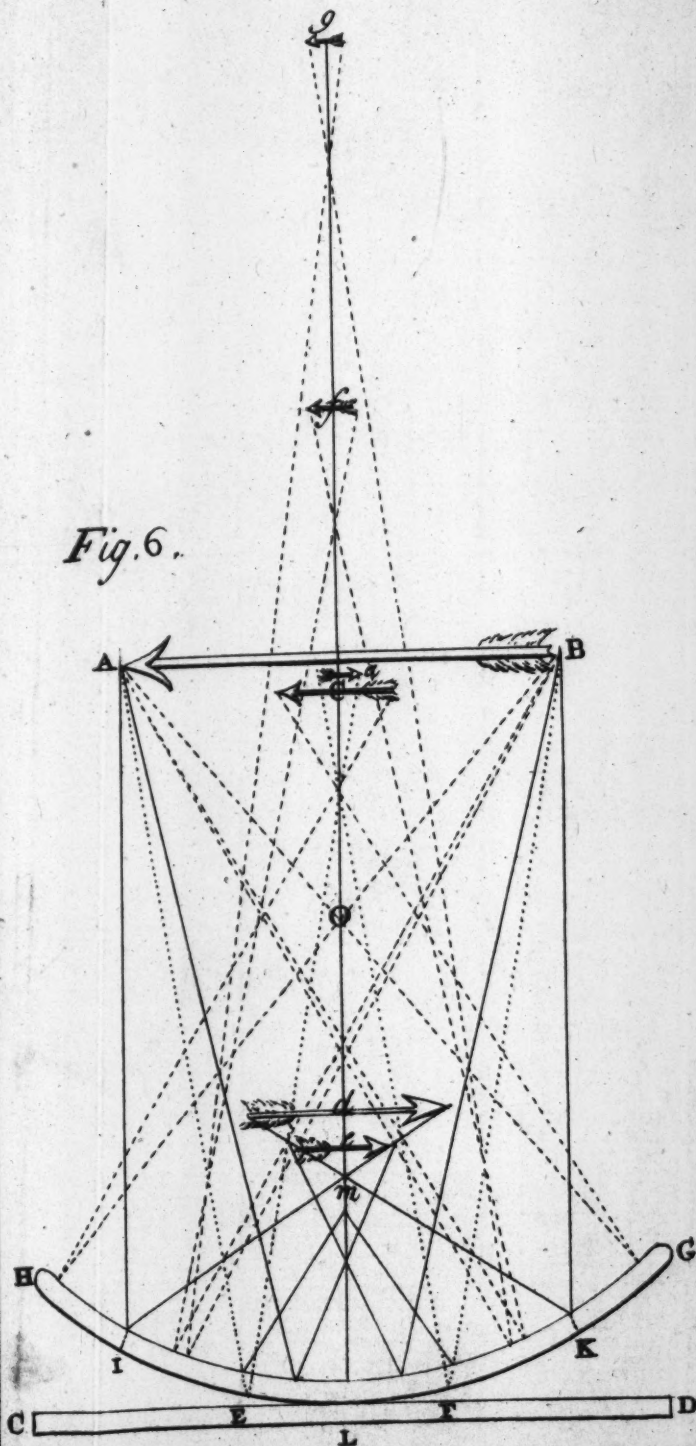




Fig. 6.



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A 2, which is more than the Moiety of A a. It will be also observable, that A 3 is more than a Tierce of A a, and so of the rest; and that consequently the Object A, Fig. 2, which appears as large again as the other Object B, of equal Magnitude, must be a little more than as near again as that other Object B. Or, which is the same Thing, this other Object B, must be at twice the Distance as the Object A.

It is still farther evident, that the Openings of the Angles A 3, A 4, A 5, and A 6, Fig. 4, are so much the less separated one from the other, as the Angles are more acute, or come from a greater Distance. The farther one goes in counting 1, 2, 3, 4, 5, 6, the nearer are these Angles, and the less Difference there is between them. In the mean while, if one conceives the Train of Objects carried on to a much greater Length, or even to an Infinity, this infinite Series of Objects ranged upon A K will have no more than the Opening of the Angle A 6 to partake of. So that there will be in this Opening of the Angle an infinite Series of Images all differing in Magnitude. Therefore their Difference will be infinitely small. Hence it is, that at a great Distance, scarce a hundred Toises of Separation between two Objects will cause some Difference in regard of the Magnitude of their Images; which is the Reason why our Judgment on the Magnitude of very remote Objects is so uncertain.

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The third Figure exhibits the same Thing, by supposing the visual Axis perpendicular to the middle of the Objects, or the optic Isosceles Triangle.

It is also visible in the Figures 3, 4, that without this Curve, which measures and bounds the optic Cone, the Rays carried on to the upright Line A 1, parallel to the Objects I, II, III, &c. would form Images whose Magnitude would be exactly in a reciprocal Ratio of the Distances, that is to say, as large again, when the Objects should be as near again, &c.

For we learn from Geometry, that in a rectangular Triangle, Fig. 5. if the Angle C be divided into several equal Parts, 1, 2, 3, the opposite Side AB will be divided into several unequal Parts AD, DE, EB, of which those will be the largest, that shall be the most remote from the right Angle A. Because the farther the Side AB is extended from the right Angle A, the wider it keeps from the Arch A 1; the larger Spaces the dividing Rays, 1, 2, 3, run over, in order to reach the Side AB, and the greater Distances they leave between them.

On the other Hand, if one divides the Angle C, Fig. 6. or the Arch A, into Parts unequal and proportional to the unequal Parts of the Side AB of Figure 5, but in a reversed Order; to wit, the greater Part being placed near the right Angle A, Fig. 6. and the smaller Part the farthest

farthest from this Angle, the Side AB will be divided into two equal Parts: that is to say, the same Obliquity, or the same Departure from the Tangent AB, in relation to the Arch A 1, which, as in Figure 5, has transformed upon the Tangent, the equal Division of the Arch into a Division unequal, and ever the larger the remoter it is from the right Angle; this Departure, I say, operating upon these Inequalities disposed in a contrary Direction, must reciprocally efface or destroy these same Inequalities which it has produced, and restore upon the Tangent AB the Equality given in the former Problem. Because here the smaller Part becomes placed overagainst the greater Departure, and receives on that Account the greater Addition; while the larger Part is placed near the right Angle, and so receives the less Addition. In short, this second Operation is only the first reversed. Therefore it must restore the former given Magnitudes, or equal Parts, as, in Arithmetic, Addition and Multiplication restore the Numbers that were sunk by Subtraction and Division.

Now the Triangle of Fig. 6. resembles exactly the inner optic Triangle of Fig. 4. and the two rectangular Triangles, in which one may include the Isosceles Triangle of Fig. 3. by looking on its Axis, or its Height, B C A, as the Side common to both Triangles. In these rectangular optic Triangles, all the Angles are likewise

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wise unequal, and by so much the larger, in respect of their Distance, as they are nearer the right Angle. Wherefore these Angles, lengthened even on a plain Base, must also lose their Inequalities, and, consequently, be perfectly in a reciprocal Ratio of the Distance of Objects. However, I voluntarily resign these profound and more or less abstruse Points to greater Geometricians. As to my own Geometry, take the following Specimen of it.

Decisive
Experi-
ments on
the Mag-
nitude of
Images at
different
Distances.

I procured some human Eyes and some Eyes of Animals, and stripped their Bottom of the Sclerotis, and the Choroides, when they came from young Subjects. I let the Choroides remain on those that had belonged to old People, because in their Eyes the Choroides has lost its black, and is sufficiently transparent. I disposed equal Objects at unequal Distances, as at one Foot, two Feet, three Feet from the Eye destined to receive the Images. I placed a Wax-Candle-Light at each End of the Objects, in order more distinctly from its Clearness to ascertain the respective Bounds. I afterwards measured the Spaces these three Objects took up in the Bottom of the Eye, and found that their Spaces were exactly enough proportioned to their Proximity; that the Object at the Distance of one Foot was thrice as large as that placed three Feet off, and as big again as what was at two Feet's Distance, measuring with a Compass.

The

The Bottom of an Eye laid open does not easily preserve its regular Figure. The Eye of ^{The} ~~SIGHT.~~

a dead Person is not always full, and the Membranes and the Humours take all Sorts of Forms between the Fingers. These Defects are partly rectified by supporting the Bottom of the Eye with a transparent Paper. But the Bottom, by this means, becomes flatted, and the Figure of it approaches to the strait Line A 1. Fig. 4.

Then the most open Angles are no longer cut off by the Curve A, a; and it is undoubtedly for this Reason, that the Magnitude of Images appears proportioned to their Proximity, as much as one can discover by a mechanical Operation. But it is to be supposed, that in a living Eye these Defects no ways occur, and that this Organ being exactly enough spherical, the Images of neighbouring Objects suffer in it the small Diminution demonstrated by Geometry in the Triangles measured by an Arch.

To remedy the Inconveniencies arising from the Softness and Variableness we have been observing in these Eyes, I ordered an artificial Eye to be made of more than four Inches Diameter, furnished with a Glass Cornea and CrySTALLINE Humour, or with the Lens of a Focus proportioned to this Diameter. The Bottom of this Eye was extended on a transparent Paper perfectly plain, by reason of the Difficulty of making a Bottom of this Paper regularly convex. I exposed this Eye to the preceding Objects,
and

The and farther found that the Magnitude of Images
SIGHT. was exactly in a reciprocal Ratio of the Distance
of Objects, as small again, when the Objects
were as remote again, &c.

In order to render the Differences of Images more perceptible, and less exposed to inevitable Errors in the mechanical Measures, I augmented the Distances, and made use only of two Objects. I placed the near Object at a Foot's Distance, and the remote Object at that of ten Feet from the Eye. The Image of the near Object took up, on the Bottom of this Eye, the Space of three Inches, four Lines, and a half, of Diameter; that of the remote Object had more than four Lines, and this last Magnitude, carried ten Times with the Compass over that of the neighbouring Object, measured it exactly. In a Word, the Image of the Object at ten Feet Distance was just a tenth Part of the Image of the Object at that of one Foot. I have repeated this Experiment twenty Times without finding the least Variation. The strait Figure of the Plain, that receives these Images, is undoubtedly the Cause of this Proportion, for the Reasons assigned above. It is also possible, that Refraction which acts more forcibly on the Rays of remote Objects, has some small Share in it. However that be, it will always follow, that, from the spherical Figure of the Eye, there never can occur any considerable Alteration in this Proportion. These are incontrovertible

testable Facts, and of Course such as both Physics and Geometry itself must submit to.

Not only Perspective is founded on the Principles we have been expounding in relation to the Magnitude of the optic Angles, and the Images they convey; but it is on those likewise depends all the Mechanism of Telescopes and Microscopes, of Glasses and polished Surfaces, which either enlarge or diminish Objects:

When one looks at the Object d, Fig. 2. Pl. Effects of XII. with the naked Eye, the Cone of Light^a Convex which this Object transmits to the Eye forms the Opening of the Angle, e, f, as in Fig. 1. and we see this Object in its natural Magnitude, with respect to its Distance. If we then place a lenticular Glass before our Eye g, h, this convex Glass collects the collateral Rays g, h, which without that would not enter the Pupil. Hence the Eye is penetrated with a luminous Cone of greater Dimension, and with a larger Image than what would naturally present itself. It refracts besides all the oblique Rays in determining them to the Perpendicular, and, consequently, in making them cross in a wider Angle. By that Means it transforms the visual Angle, e, f, into the Angle b, c, from whence results an Image of the Object, d, a great deal larger than the former. Thus the Imagination, deceived by its surest Rule, looks upon this Object as of a greater Extension than it was before.

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The All this will be intirely reverfed, in case we
SIGHT. place before our Eye a concave Glas, h, h,
Effects of Fig. 3. Pl. XII. The great Statue, g, g, inde-
a concave pendently of this Glas, would form in our Eye
Glas. the large Angle, or the large Image, b, c.
 But when the first Rays, g h, g h, present
 themselves to the concave Glas, they are turned
 from the Perpendicular and from the Axis of
 the Eye, and approach to fall very wide of the
 Pupil in L, L. The subsequent Rays do the
 same, even to the Rays, m, m, which being
 very near the Axis are the only ones that can
 fall on the Pupil in spite of the Refraction.
 These Rays, m, m, are therefore those alone,
 that can convey to the Eye the Image of
 the Statue: but these Rays can form in the
 Bottom of the Eye but a very acute Angle, but
 a very small Image, e, f. The great Statue,
 seen through the concave Glas, h, h, will ap-
 pear of course very small.

These Accounts of the Effects of convex and
 concave Glasses might satisfy a simple Natura-
 list. But a Naturalist, that is versed at the
 same Time in Anatomy, must farther see these
 different Determinations of the Rays upon the
 Parts themselves in the Bottom of the Eyes. I
 therefore took some Eyes stripped to their Bot-
 tom, as in the preceding Experiments, and,
 after having made some illumined Objects fall
 upon them and remarked their Angles, I placed
 before these Eyes convex Glasses, and saw the
 Angles

Angles enlarge themselves in proportion to the Convexity of the Glasses. I afterwards made use of some that were concave, and found these same Angles diminish in the same Proportion.

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What a concave Glass effects by Refraction, a convex polished Surface does also by Reflexion. But we shall not proceed to the convex Surface, without having first explained the more simple Phenomena of the plain Surface, and said a Word or two concerning the Nature of Mirrors, or of Surfaces, that reflect, in the most lively manner, the Images of Objects.

The Na-
ture and
Effects of
Looking-
Glasses.

A Mirror is made either with a polished Body, such as Steel, that immediately reflects Images, or with a polished and transparent Body, as Glass is, behind which is applied a Matter endued with a Property of reflecting Light; which is generally a Plate of Tin. This Plate is laid upon a very smooth Stone, and covered all over with a Bed of the purest Quick-silver. If one has the Curiosity to behold ones self in this Bed of Quicksilver, it would appear, that there is no smooth Surface in Nature, which transmits an Image so exact and distinct. The Glass is then placed upon this Bed of Mercury, and loaded with a good deal of Weight to press out what is superfluous, and leave only that which is necessary to fill the Pores of the Surface of the Glass, and of the Plate of Tin, and thus to fasten both Surfaces together. This Composition is afterwards placed in a sloping Direction,

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Direction, and then in an upright one, in order to drain the supernumerary Quicksilver, and then the Glass is tinned over. Now it is this Plate of Tin, impregnated with Quicksilver, and fastened by it to the Glass, that reflects the Images, or at least the most lively of them. For in a thick Glass, on holding it in a particular manner, we discern two Images, one reflected by the Tin, the other by the Surface of the Glass. This latter Reflection is a very faint one, and requires some Art to discover it. The Light, on the contrary, reflected by the Tin, is strong and lively, and ordinarily effaces the former. In the meanwhile, if one has a mind to see distinctly this feeble Light reflected by the Surface of the Glass, all one has to do, is to place behind a Glass, that is not tinned, some black Substance to absorb the strong Light which effaces the other; such as black Velvet, black Paper, or a Hat. We see ourselves but faintly in this second Kind of Mirror, because the Image is formed only of the Light reflected by the Surface of the Glass, which Light is ever weak in comparison of that which pierces the Glass, and is reflected by the Plate of Tin.

In order to expound the Effects of a plain Mirror, let us suppose the large Statue, Fig. 4. Pl. XII. to be between our Eye and a plain Mirror A, A, a little on one Side, to give Passage to the Reflection towards our Eye, C.

The

The Light, which falls on all the Points of the Statue, rebounds all around in every Point of the circumambient Space, as we have seen above; and, consequently, this Light must fall on all the Points of the Surface of the Mirror, by which it is likewise reflected from every Part. But our Pupil takes up no more than a single Point of this whole Circumference where the Light is reflected, and can receive but one of all the luminous Cones distributed to an Infinity. Now by the Rule, that the Angle of Reflexion, is equal to the Angle of Incidence, the sole Cone of Light, which falls on our Eye, situated as in Fig. 4. is the reflected Cone A, C, A, formed by the Rays which fall upon the Mirror at the Points A, A, and which tend to make in the Bottom of our Eye, the large Opening of the Angle, b, c. For the Rays E, E, which are going to fall towards the Extremity of the Mirror on h, are reflected at a Distance from the Statue, and still farther from our Eye. The perpendicular Rays EI return upon themselves, and can never fall on our Eye. All the Rays E, K, K, nearer the Axis C, X, than the Rays A, A, approach to cross one another on this Axis much on this Side of our Eye, and to be lost at last on the lateral Quarters, m, m. Infomuch, that the only Rays, which can fall on the Pupil, are the Rays A, A. The Opening of the Angle, b, c, which this Cone of Light forms at the Bottom of our Eye, gives

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The us the natural Image of the Statue, as if we saw
SIGHT. it behind the Mirror, and as far behind the
 Mirror, as it is actually distant from it before.
 For Example, if the Statue be six Feet before
 the Mirror, it will appear to us six Feet behind
 it, because the luminous Cone that conveys
 to us this Image, becomes narrower and nar-
 rower from the Statue to the Mirror, and
 from the Mirror to the Eye, as is shewn by the
 Figure. So that the Cone broken by the Re-
 flection, is of the same Length, the same Fi-
 gure, and of the same Opening, as if the Statue
 were six Feet behind the Mirror, altho' it be
 six Feet before it. Wherefore the Image im-
 printed on our Eye will be the same as if the
 Statue were really six Feet behind the Mirror;
 consequently, the Statue will appear to us six
 Feet behind it, and in the Magnitude that
 would be natural to it in this Situation.

Effect of
 a convex
 Looking-
 Glafs.

Now let us substitute a convex Mirror, B, B,
 Fig. 5. Pl. XII. instead of the ordinary Mir-
 ror. The pointed Rays are those which fall
 upon the plain Mirror, A, A, of the preceding
 Figure, and there go to form in the Eye the
 natural Angle, b, c. But here these pointed
 Rays, coming to fall on the convex Surface,
 B, A, far from returning towards the Eye,
 are reflected towards d, at a great Distance
 from the Place where the Eye is situated. Of
 all the Rays that come from the Statue to fall
 on the whole Surface of the convex Mirror,

the

the only Rays capable of being reflected towards the Pupil, are those not pointed, B, B, which go to make in the Eye the Angle e, f. This Angle is very acute, in comparison of the Angle b, c. Therefore the Statue will appear extremely small, in regard of what it would do in the former Mirror, A, A.

The
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The concave polished Surface performs likewise by Reflection what the convex Glass does by Refraction; that is to say, both one and the other enlarges the Objects, but it is in particular Effects of Points of View: in others the concave reflecting ^{a concave} Surface diminishes the Objects like the concave Looking-Glass. Glasses, and the convex reflecting Surface. These curious Phenomena lay claim to a little Discussion.

The plain Mirror is always our Rule of Comparison. Place then the Arrow, A, B, Pl. XII. Fig. 6. overagainst the ordinary Mirror C, D, and imagine your Eye to be before the middle of this Arrow; or, if you will, suppose your Face to be at the Place of the Arrow itself. Your Image reflected in its natural Magnitude will be as the small reversed Arrow, a, formed by the luminous Cone, in small Points, which approaches the plain Mirror in E, E. It is to be remembered, what we said above, that this Arrow, reversed in the Bottom of the Eye, must appear right in our Regard. So that altho' the Image of the Arrow, or of your Face,

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be here inverted in your Eye, these Objects notwithstanding will seem in a right Position.

Before this plain Mirror, C, D, place the concave Mirror, G, H, and its Concavity will collect towards the Axis, L g, the vast Cone of different Reflections, a very small Part of which are expressed in the Figure. The luminous Cone in little Points, that fall on the plain Mirror in E, F, and went to form the small Arrow reversed, a, no longer keeps the same Track, when reflected by the concave Mirror, but is terminated very near the Mirror at the Point, m, and on that Account we can no more receive its Impression.

What then is the Cone of Reflection the Eye will receive placed before the middle of the Arrow A, B? It is capable only of receiving the oblique Rays, AG, BH, which on crossing one another strike at the Extremities, H, G, of the Mirror, and return to cross afresh in the Eye, and there to point the Arrow, C, thrice as large as the natural Image, a, transmitted by the plain Mirror, C, D. But the great Arrow, C, is in the same Situation at the Bottom of the Eye, as the first Arrow, A, B, is, that is wide of it, by reason of the double crossing of the Rays. Consequently this Arrow will appear reversed in this Place. For every right Object has its Image inverted in the Bottom of the Eye, and reciprocally all Objects, that have their

their Images right in the Eye, appear to us reversed.

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SIGHT.

In order to see the Image of the Arrow A, B, or rather one's own Image in a right Position, we must approach the Mirror in the Points, d, e, m, &c. Because we then receive the luminous Cones, that have been to strike the Mirror directly, without any previous crossing, and which, on that score, cross only in our Eye, according to their ordinary Manner. Now in these near Points of the Mirror, the Object will appear still a great deal larger than in a natural State, unless the Eye almost touches the Glass. For then our Visage appears pretty natural, because the Cone of Light one receives is very small. But in proportion as one draws back, the Visage appears more and more monstrous, for the same Reason as the Arrow d is larger than the Arrow e, being the Base of a greater Triangle.

If we place ourselves opposite to the same Mirror in the Space, o, situated between the Point where the Object appears right, d, and that where it appears reversed, C, we shall see but one Chaos of Light; because the Rays cross one another in this Space, and all the Parts of the Images are there confounded. Draw back to C, and the Image appears still larger than Nature, but reversed, for Reasons explained above. Continue to draw back, as in f, g, the Image will still remain ever reversed,

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but

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but will become smaller and smaller, and even so little, that at last it will equal in Minuteness the Image reflected by the convex Mirror. So that the Image reflected by a concave Mirror, at a middle Distance, is always much larger than Nature; and when this great Image is right as in m, then the more one retreats from the Glass, the more this Image is augmented. But when the Image is reversed as in C, the more one recedes from the Glass, the more is the Image diminished. The Demonstration of these curious Truths is expressed by the same Cones of Light traced in the Figure, according to the Laws of Reflection.

The Mag-
nitude of
Images
farther va-
ries ac-
cording to
the Kinds
of Eyes
which re-
ceive
them, and
the more
so pursuant
to the dif-
ferent
States
wherein
they occur.

Objects appear to us so much the larger, as they transmit to our Eye a larger Image, and a more extensive Cone of Light. And this luminous Cone is so much the more extensive, as the Object is larger or nearer to the Eye. But do we imagine that the same Object, at the same Distance, transmits to the Eyes of all Animals, and all Men, an Image of the same Magnitude? Undoubtedly we do not. The Magnitude of Images, and that of the Picture including them all, depend likewise on the Disposition of the Organ itself. For Example, an Eye smaller and more twinkling than ordinary, and that has a more convex Crystalline Humour, receives a smaller Picture in Proportion, and lesser Images; for the same Reason, as when a very convex Lens is placed on the Inside

Inside of the Hole of the dark Chamber, there occurs a very minute Picture. In the mean while it has been demonstrated above, that a like Lens placed before the Eye, or on the Outside of the dark Chamber, considerably enlarges Objects. This Contrast perhaps may be perplexing; but it is no hard Matter to comprehend these opposite Effects of the same Instrument differently applied. The
SIGHT.

The Rays that convey the Images from the Object to the Bottom of the Eye, or on the Pastedboard of the dark Chamber, form two Cones joined at the Top. The first Cone has its Base on the Object, and its Top in the Pupil, or in the Hole of the dark Chamber, where the Rays cross. The second Cone has its Top at the same Crossing, and its Base on the Choroides, or the Pastedboard that receives the Images of the dark Chamber. The Lens one puts before the Eye, or before the Hole of the dark Chamber, is placed in the exterior Cone a little before its Crossing. It collects in this Crossing a larger Cone, as has been demonstrated, and causes it to cross in a wider Angle: and by that means gives a larger Base to the second Cone, which thus renders the Images the larger. The Crystalline Humour, on the contrary, or the Lens one puts within the Hole of the dark Chamber, is placed in the inner Cone near its Top; which, by collecting the Rays of this Cone towards the Axis, renders the Base of

The
SIGHT.

it smaller. Consequently, the Images contained in this Base are also diminished by these Lens's, and that in proportion to the greater Convexity of them.

Now there is a wider Difference between the Eyes of several Kinds of Animals, than there is in Regard of all the Sorts of Lens's. It is therefore evident, that the diverse Species of Animals, and that Men in general do not see the same Objects of the same Magnitude, nor a like Quantity of Objects at a Time.

I will not insist on these known Truths; but I go farther, and aver, that the same Person, with the same Eye, sees, the same Day, and even the same Moment, Objects sometimes larger, sometimes smaller, according to certain Motions incident to this Organ, and particular Dispositions that occur.

The most frequent among these Motions of the Eye, that change the Magnitude of the visual Angle and of Images, are those which are made on our looking at a near Object, and presently afterwards at one that is remote.

The Eye is dilated, in order to see neighbouring Objects. The Diameters of its Humours, and its Lens's, are drawn into a narrower Compass, and their Surfaces become more convex. Consequently, the Eye is then in the Case of the small twinkling Eye, or the very convex Lens, which we have just been speaking

speaking of. It gives therefore on this score, ^{The} smaller Images than it would do in any other ^{SIGHT.} Figure. But this same Eye is dilated, the Cloth that receives the Image is more remote, and this Image ought to be so much the larger. Should one of these Causes make amends for the other?

On the contrary, in order to see a distant Object, the Eye contracts itself, is flatted by the Poles, and enlarged according to its Equator. The Diameters of the Humours are augmented, their Surfaces flatted, and this Eye becomes in the State of the flat Lens, which gives a more extensive Picture. So that on this Account one sees remote Objects larger than one would do without this Alteration of Figure: that is to say, Allowance being made for the Distance, remote Objects appear larger, than neighbouring ones do. But this same Eye, whose Humours become less convex, is likewise flatted, its Bottom advancing towards its Entrance. The luminous Cone of course grows shorter, and the Images consequently smaller. Are these contradictory Effects equally compensated? Or is the flat or convex Figure of the Humours predominant over the Contraction or Dilatation of the Eye? I shall communicate the Observations that seem to me to decide in Favour of the latter Opinion, viz. that the Eye on looking at a near Object, renders the Images smaller, notwithstanding its Dilatation, and that the

The the Eye, which looks at a remote Object, exhi-
SIGHT. bits the Images larger notwithstanding its
 Contraction.

Observa- Casting a random Look at a feeble Light,
tions on situated very near me, I was surpris'd to fee
the Varia- this Light thrice as big as Nature, and encircled
tion of the with Rays. I looked at it afterwards with At-
Magni- tention, and it resumed its natural Magni-
tude of tude. I have since that, frequently repeated
Images. this Experiment, either with a feeble Light, or
 with the small luminous Point which results
 from a very convex polished Surface, and
 it always was attended with the same Suc-
 cess.

When I looked attentively at the feeble Light,
 or at the luminous Point, these very near Objects
 would oblige me to dilate my Eye, and to ren-
 der its Humours more convex, from whence I
 received a small Image. I then looked at them
 indistinctly, that is to say, with my Eye relaxed
 in its most natural State, and spherical Figure,
 which gave its Humours less Convexity. My
 Eye therefore at that Time became in the Case
 of a flatter Lens, and thus gave me a larger lu-
 minous Point, and a more open visual Angle.
 One cannot make the Experiment with a strong
 Light, by reason its lively Impression does not
 permit the Eye to relax itself.

Another Time I looked, thro' the Glass of a
 Casement, at a very remote Country-Seat, which
 appeared to me sufficiently large. I after-
 wards

wards fixed my Eyes on the Glass itself; and it seemed to me a great deal smaller, than when I looked at it directly. Since that Time I have made repeated Experiments of this Matter, and always found the same Circumstances.

The
SIGHT.

On looking directly at the distant Seat, my Eye was flatted. The Angle, which this Seat transmitted to my Choroides, was therefore larger. On fixing my Eyes on the Glass of the Casement, I dilated for this near Object the Globe of my Eye, and rendered its Lens's more convex. The Image of the remote Seat, falling on these more convex Lens's, was there refracted to a greater Degree, and conveyed on my Choroides a smaller Angle, and of course a minuter Image.

I shall recount still something more extraordinary on this Variation of the Magnitude of the visual Angle, or of the Image of Objects.

Last Winter I was in the Country. In the Night it froze hard, and there fell a little Snow. On going out of my Chamber in the Morning, all Objects appeared to me sensibly smaller, than they had done the Evening before. I could not help being very much surprised. But, ruminating on this Effect, I recollected that a long Time ago in a dry and clear Season, I had frequently been astonished to see Objects with a Precision, where I had a confused Notion that there was something more

Images are
smaller in
very cold
and very
light
Days.

in

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in the Matter than a bare Exactness. These confused Notions are the Seeds of Discoveries. This in particular had prepared me to remark in the preceding Experiment the Diminution of the Magnitude of Images by the hard Frost and the Snow; and some few Reflections soon made me perceive, that my Discovery was a necessary Consequence of the Nature of the Eye, and of the Principles I have been expounding.

The Images painted in my Eye are smaller in Proportion to the Smallness of the Diameter of the Eye, and the greater Convexity of its Humours. *Peter* sees Objects smaller than I see them, if he has smaller Eyes, and more convex than I have. If there are Times, Days, or Moments, when I myself have Eyes as small, as contracted, and as convex as those of *Peter*, I then see Objects as small as he sees them, and smaller than I see them ordinarily.

This is exactly the Case of Eyes, struck with the Cold of Frost, and the Brightness of Snow. Both the one and the other of them, making a strong Impression on these Organs, excite in them a forcible Contraction. The Eyes struck in this Manner are lessened in all Directions, and principally according to their Equator, by the Contraction of the Iris and Corona Ciliaris. All the Humours participate of this kind of Condensation; and, consequently the Eye is smaller, more convex, and receives of course a smaller visual Angle, and not so large an Image.

I became notwithstanding apprised of this Diminution of Images very accidentally. As these diminish universally after the same Manner, there remains no farther Rule of Comparison. On which Score this is no sensible Phenomenon, and, in order to perceive it, I must have had the Magnitude of the Images of the preceding Evening very present to my Idea. But it is not the less certain, as the Figure of the Eye contributes to the Magnitude of Images, that we must necessarily see Objects the more or less large, proportionably to the greater or lesser Degree of Elasticity the Temperature of the Air, or our Health, imparts to our Solids, or of Rarefaction accruing from either of those Quarters to our Fluids. Thus in hot, faint, close, hazy Weather, in a weak and languishing State of Health, and in certain plethoric Cases, the Eye being then relaxed and dilated to a greater Degree, we see Objects so much the larger, and in a cold, dry, clear Season, and in a good Disposition of the Organs, they appear smaller: inasmuch as our Fibres and our Eyes, from these Contingencies, acquire a greater Elasticity and Contraction, and our Fluids become much less rarified.

Since I made this Discovery, and have been guarded against the Rule of Comparison, I plainly perceive that a very illumined Object seems smaller, and an Object feebly supplied with Light appears larger. The Reason of
this

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SIGHT.

this is evident. A strong Light puts the whole Globe of the Eye on contracting itself, and a feeble one leaves it relaxed and dilated.

The second Rule, whereby to judge of the Magnitude and Distance of an Object, is the Confusion or Clearness of its Image.

How sure and geometrical so ever be the Opening of the visual Angle to determine the absolute Magnitude of Images, it cannot notwithstanding singly constitute a Rule for judging of the Magnitude of Objects relatively to their different Distances. It will very well decide between two Objects at an equal Distance, which of them is the larger; but it will never alone determine this Distance of Objects, nor consequently their Magnitude, which diminishes in Proportion to the Distance. The Reason of this Uncertainty of the visual Angle is, because in the same Angle, Fig. 1. Pl. XII. one may place a Series of Objects of different Magnitudes, 2, 3, 4, 6, provided they are ranged at a Distance proportionable to their Magnitude.

All these Magnitudes, 2, 3, 4, 6, would therefore form in the Eye the same Angle, and have there an Image equally large, tho' they would each of them be of unequal Magnitude.

The visual Angle, as intirely geometrical as it is, will then deceive us, if we compare it with the Degrees of the Distance of the Object. A Tennis-Ball, seen at the Distance of some few Inches, will form a visual Angle as large as a Turret a hundred Paces off; and on that Account this Ball will appear as big as such a Turret, in case the Proximity of the Ball does
not

not oblige one to abate as much of its apparent Bigness, as the Distance of the Turret would make one add to the Magnitude of its Angle. The
SIGHT.

I therefore rate each Magnitude of the visual Angle, at its just Value, by the Comparison I form of the respective Distance of the Objects. But by what Rule shall I judge of this Distance? By the *Confusion of the Image* itself, contained in the visual Angle, or by the *Body of Vapours*, which the Distance raises around the Object, and also by the Length of the optic Angle formed by the Concourse of the optic Axes of each Eye.

I observed above that, on looking at an Object with both Eyes, both the Axes are united on this Object. When this Object is near, as O, Fig. 2. Pl. X. the Angle formed by these Axes is very short, or open; and both Pupils are turned in a greater Degree one towards the other. On the contrary, when the Object is remote, as G, were it on the same Line as the former, the Pupils would recede one from the other to form a longer and more acute Angle; and it is conceived, that in a great Distance the Pupils become parallel.

We are not insensible, that these Motions, and these Situations of the Pupils and optic Axes, vary according to the Distances of Objects. We are habituated to distinguish them, and thereby sufficiently enabled to form a Judgment in regard of those Distances.

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SIGHT.

I do not at all doubt but that the more or less extended Series of different Bodies, situated between the Objects and us, is a farther Assistance in respect of this Judgment. But the Concurrence of the optic Axes of both Eyes is itself necessary in order to distinguish exactly this Series of intermediate Bodies. So that this Concurrence of the Axes, and the Length of the Angle they form, is the first Principle of this Judgment. From thence it happens that when we see but with one Eye, we no longer distinguish Distances, and that looking thus even from very near, we cannot lay the End of our Finger on any set Place. Nay, this Finger will even hide the destined Object, and were it a Foot off, the Finger corresponds with it as justly, as if it were only at the Distance of a Line. But if we open the other Eye, this, which sees our Finger and the Object sideways, will discover between them a great Space, if they are a Foot distant, and but a small one, if they are very near; and by that means we may place our Finger with Certainty on the designed Object. See Pages 199, 200, &c.

Cause of
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of Va-
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which co-
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mote Ob-
jects, and
the Use
Painting
makes of
them.

The Confusion with which we see an Object, is the second Rule to judge by, that it is very remote. This Confusion of the Image of a distant Object proceeds from the Air, and Vapours, which extinguish Part of the Rays that compose this Image.

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The Narrowness of the luminous Cone of remote Objects, contributes likewise to this Extinction. It is even astonishing, that so small a Filament of Image should not be intirely effaced on meeting with such a prodigious Quantity of Obstacles.

The Confusion of distant Objects is therefore a Phænomenon the most conformable to the Laws of Physics. It is even a Fact established thro' the whole System of Nature, which no one can be unapprized of, if they will but open their Eyes. Painting, the Mimick of Nature in this Kind, in order to express the Distance of Objects in Perspective, after the Diminution required by the visual Angle, covers these Objects with a Lay of Vapours proportioned to that Distance. The Degree of this Lay constitutes even one of the most delicate Circumstances of the Art. In a Landscape, an Artist will represent on the Canvas a Rat and a Camel of equal Magnitude. Because the Rat, with glaring Colours, will project a good deal, and the Camel, scarce visible, will seem to be lost in a Deepning, where we ourselves lose the Idea of the Cloth on which he is painted. In Nature, we see above a Wall two Steeples of equal Magnitude; but we see one of them with the Confusion that still results from any considerable Distance, while we view the other very distinctly, even to the Ornaments of Architecture. From whence we judge the latter to be very near us, and the

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How Fogs
enlarge
Objects.

other to be as remote. And tho' their Image be of the same Magnitude, we conclude nevertheless, that the distant Steeple is by far larger than the other; inasmuch as we know by Experience, that Distance diminishes Objects; and that a remote Object, which appears as large as a neighbouring one, must necessarily be a great deal larger than this latter. It is by the same Rule, that the Eye being deceived, sees Objects the larger in foggy Weather, and the Moon in the Horizon a great deal bigger than in any other Part of the Heavens. A Fog, by covering these Objects with thick Vapours, makes them appear more remote than they are; but as they cause no Diminution of their Bulk, we imagine them more considerable. On taking a Walk in a Fog, any Person in view seems to us of gigantic Stature; by reason we see such a Person confusedly, and as at a great Distance; when, the Object notwithstanding being just upon us, a very large Image is transmitted to our Eye. Now we judge a remote Object to be large, that imprints on the Eye a large Image. But in this case we soon recover from the Mistake, and by that means perceive the Origin of it. For we are surprised to find ourselves in an Instant quite near this Person, whom we imagined to be at so great a Distance, and whose Size no longer appears extraordinary.

It

It is by the same Enchantment, that the Vapours of the Horizon make us see the Moon ^{The} as confusedly, as if she were as far off again; ^{SIGHT.} Why the and these same Vapours diminishing nothing of Moon ap- the Magnitude of the Moon's Image, the pears lar- the Soul, having no Idea of the real Magnitude of ger in the this Planet, concludes her as big again: be- Horizon cause on seeing an Object two hundred Paces than in distant, under an Angle as large as that of another Object seen at a hundred, she judges the Object two hundred Paces distant, as large again as the other, unless apprised of the real Magnitude of these Objects. ^{her Me- ridian.}

Father *Mallebranche*, followed almost by all our Naturalists, explains this apparent Magnitude of the Moon on pretty near the same Principles. But he says one judges the Moon at a greater Distance in the Horizon, because there then appears between her and us a long Series of Mountains, Vallies, Woods, &c. Whereas in her Meridian she seems only a little above our Steeples. Now a Word or two destroys this System. If we look at the Moon in the Horizon over a Wall, thro' a Paper-Tube, or with a Telescope, we see no more of these Mountains, Vallies, &c. those Indications of her Distance, and yet she ever appears larger than she is. Some other Body therefore, foreign to these Vallies and Mountains, must interpose to enlarge her, at least in my Imagination.

The
SIGHT,

tion. And what can this be but the Vapours of the Horizon itself?

This Effect has always been ascribed to Vapours; but these Vapours have been thought to enlarge the Moon's Image, as a Lens enlarges Objects. A single Astronomical Observation has quite disconcerted this System. The Image of the Moon seen thro' large Telescopes, and measured by the Micrometer, seems as small in the Horizon, as in her Meridian. I refer the Matter to Astronomers. They are Persons of too great Penetration to suffer themselves to be imposed on by Telescopes. Their Observation confirms my Opinion. In the mean while I act with Sincerity, and shall communicate an Experiment, which has induced me to conclude, that Refraction bears some Part in regard of the Moon's Magnitude in the Horizon, let what Use soever be made of it.

Experi-
ment on
the Re-
fraction of
the At-
mosphere
of the Ho-
rizon, in
relation to
the Stars
and the
Augmen-
tation of
their ap-
parent
Magni-
tude in this
Region.

I procured a Glass Vessel, A, B, Fig. 1. Pl. XIII. shaped like a Quarter of the Atmosphere taken with a Level on the Surface of the Earth, C, or having for its Base a Tangent of this Surface. This I filled with Water. I placed a Crown-Piece in E, to represent the Stars a little below the Horizon, and my Eye in B, the Horizon of my Machine. I saw the Crown before it was at the Height of this Horizon, and saw it considerably enlarged. Wherea placing it at D, representing the Meridian and my Eye in C, I saw the Piece in its natu

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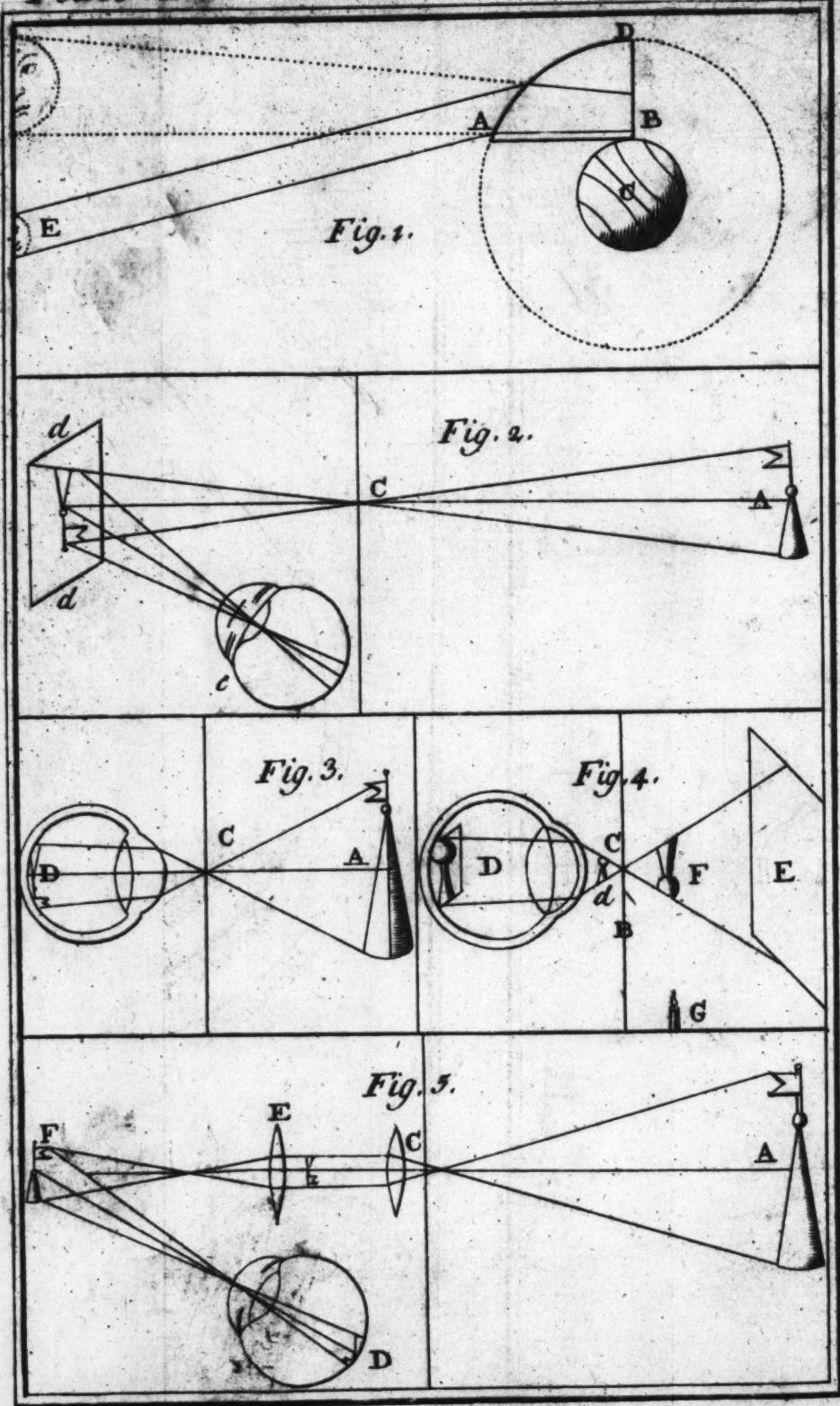


Fig. 1.

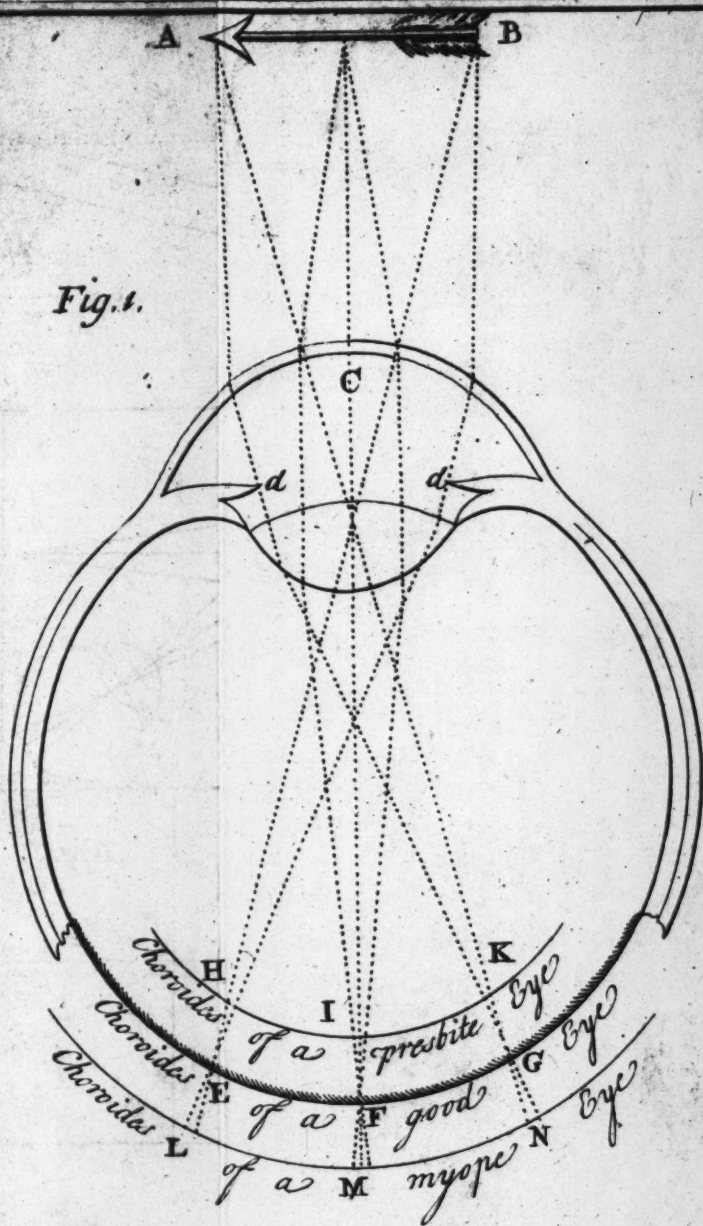
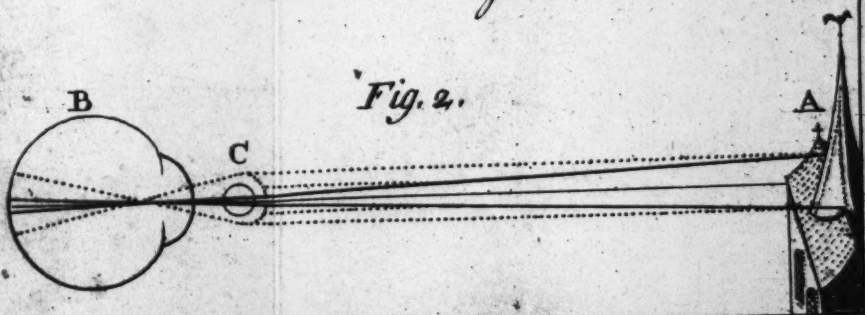
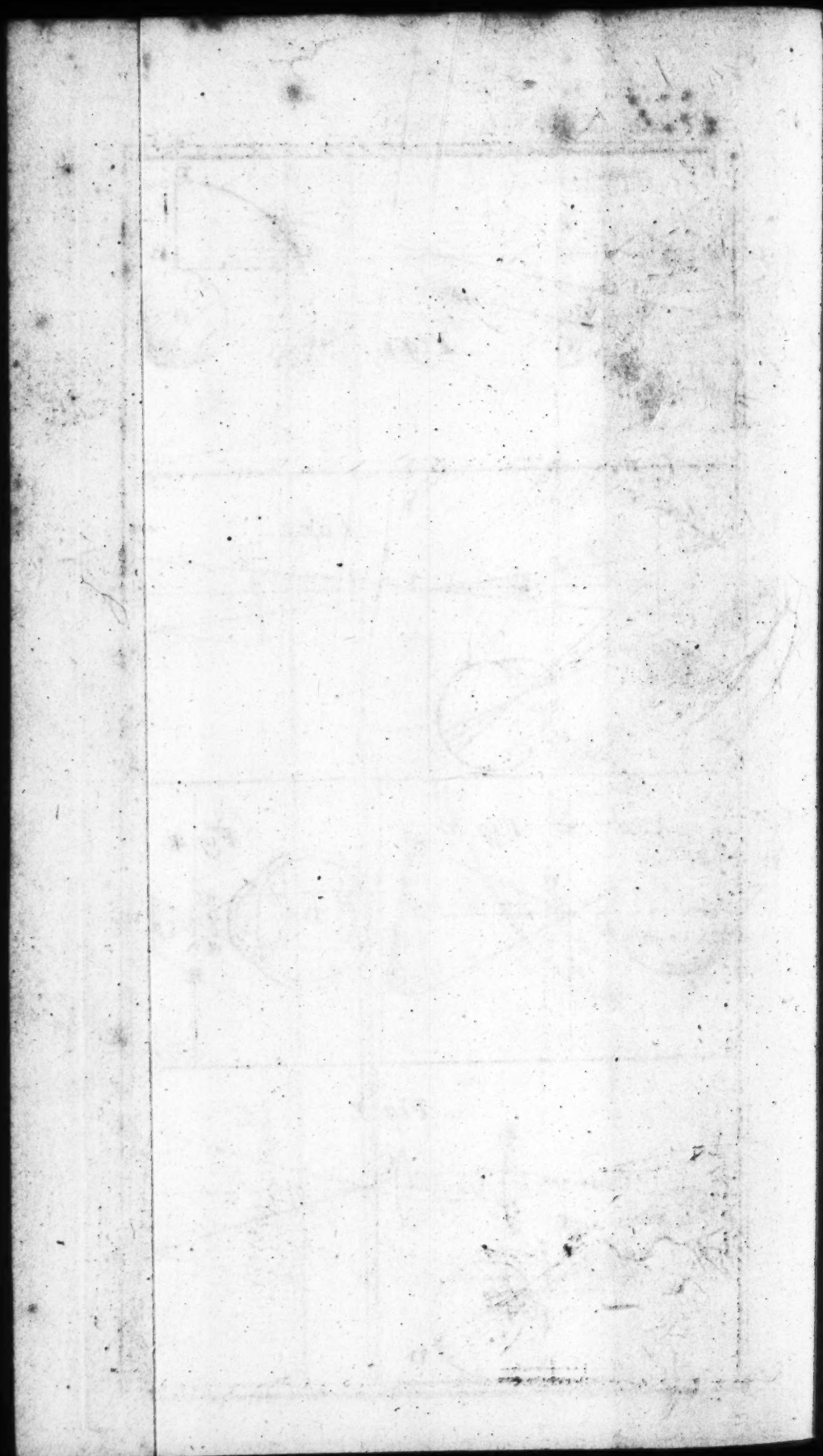


Fig. 2.





ral Magnitude. I saw it here in its ordinary Magnitude, because its Image fell perpendicularly on my artificial Atmosphere, and reached my Eye without any Refraction, or Alteration. I saw the Crown-piece before it was in the Horizon, A B, of my Machine, by reason, its Image falling obliquely on the Surface of this transparent Machine, it was conveyed to me by Refraction, before the Crown corresponded perpendicularly with this Place. This Piece appeared to me considerably enlarged, because its Rays were refracted convergently, as expressed in the Figure. The Stars are seen on the Horizon, like the Crown-piece, before they really are there. Would not this same Refraction, that makes them thus advance by their Images, enlarge them likewise as it does the Crown? This seems to me a Consequence necessarily flowing from the Laws of Dioptrics: and, in that Case, this Cause might very well concur with that I have above assigned for the Moon's and Stars appearing larger in the Horizon than in any other Part of the Heavens.

A third Rule, whereon the Soul founds its Judgments of the Magnitude and Distance of Objects, is the Knowledge we have of the natural Magnitude of certain Objects, and of the Diminution accruing to them from Distance. An Artificer, seen on the Top of a Steeple, appears at first no bigger than a Bird. But when I descry him to be a Man, I imagine him five

The third Rule whereby the Soul judges of the Magnitude and Distance of Objects, is to compare them with the known Magnitudes.

The
SIGHT.

or six Feet high, because this Measure is the ordinary Standard for Men: and at the same Time, by Comparison, I judge the Cross and Weather-Cock of this Steeple to be of much more considerable Bulk, than I believed them to be before. It is thus that Painting will express a prodigious Giant in the Space of an Inch, by placing near him a Person of common Stature, that shall reach no higher than his Ankle-Bone, and a Tree, or a House, that shall not exceed his Knee. The Comparison strikes us, and we imagine at first Sight the Giant to be of an enormous Size, altho' in reality he takes up no more than an Inch of Canvas.

Tho' this Judgment be a natural Consequence, as well as all others the Soul forms on the Situation, Simplicity, Distance, &c. of Objects, both the one and the others are made nevertheless without Reasoning, inasmuch as they are universally founded on a long Habitude of seeing; whence they degenerate with us into a kind of Instinct. Ideots, Infants, and even Beasts reason sufficiently for this, after they have lived long enough to have acquired this Habit*.

This Circumstance does not at all detract from the Necessity and Advantage of the foregoing Rules. It is a Proof only, that the repeated Use of these Rules forms in us a Facility of drawing

* It is observable by the bye, that this simple Use of Vision is a farther Proof, that Animals think, reason, and judge, after their Manner.

drawing Consequences almost without being apprised of it.

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SIGHT.

All Habitudes are only this, *viz.* a Facility acquired by repeated Acts. But these Acts, which are the Basis of the Habitude, necessarily suppose Rules. These Rules are executed with Difficulty before a Habitude is acquired; but afterwards we put them in Practice with Ease, with a greater Degree of Assurance, and as it were mechanically: This is the whole Difference.

So that altho' the visual Angle be altogether geometrical, altho' the Lay of Vapours that covers remote Objects be intirely physical, and the Consequence drawn from the Comparifon of known Magnitudes be perfectly logical, the Judgment, or rather the Estimation of the Distance and real Magnitude of an Object, is nevertheless an Art of Instinct acquired by Habitude, where Logic is of no Service in Nature. Infomuch, that in Cases where the Eyes deceive us, whether thro' the Difficulty of applying the preceding Rules, or thro' the Abuse of the Rules themselves, the greatest Logicians are mistaken as well as others; and it is in this consists the whole Magic of Painting.

But from whence proceeds this Uncertainty in regard of the most beautiful and most useful of our Senses? How in particular can we account for these Errors of Vision relating to the Magnitude, Situation, &c. of Objects? The Reason

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SIGHT.

of all this is, because the Measure of the Number of Magnitudes and Distances is not the proper Object of the Sight, but that of the Touch, or rather that of the Rule and Compass. The Sight, properly speaking, has no other Province, than that of Light and Colours. The celebrated *Monf. de Voltaire*, in his Elements of Sir *Isaac Newton's* Philosophy, relates a fine Observation, that confirms the Truths we have been establishing.

No one undoubtedly could be more in a Condition of explaining to us how Vision is performed, and after what Manner are known the Magnitude, Distance, Situation, and Figure of Objects, than one born blind, to whom has been procured the Faculty of seeing, at an Age capable of expressing what passed in his Ideas.

A singular
Observa-
tion con-
firming
the prece-
ding Doc-
trine.

“ But where to find (says this renowned Author) the proper blind Object to decide incontestably the Point in Question? In short, in the Year 1729, Mr. *Chefelden*, one of those famous Surgeons, who join Dexterity of Hand to the greatest Lights of Genius, having imagined it possible to give Sight to one born blind, proposed the Operation *. It was with Difficulty the blind Person was brought to consent to it. He had no extraordinary

* This Blind was born with a Pupil intirely closed, and the Operation consisted in making an Opening in this Part.

“ ordinary Notion, that Vision could make any
 “ great Addition to his Pleasures. Independ-
 “ dently of the Desire that had been instilled
 “ into him of learning to read and write, he
 “ had no manner of longing after Sight. He
 “ verified by this Indifference, continues Mons.
 “ *de Voltaire*, that it is impossible to be unhappy
 “ thro’ the Privation of a Good, of which one
 “ has no Idea. But, be that as it will, the
 “ Operation was performed, and succeeded.
 “ This young Man at about fourteen Years of
 “ Age, saw the Light for the first Time. It
 “ was a good while e’er he could distinguish
 “ either Magnitude, or Distance, or Situation,
 “ or even Figure. An Object of an Inch
 “ placed before his Eye, and that hid a House
 “ from him, appeared to him as big as a
 “ House. All he saw seemed to him at first
 “ to be upon his Eyes, and to touch them, as
 “ Objects of the Touch do the Skin. He
 “ could not distinguish what he had judged
 “ round by the Help of his Hands from that
 “ he had concluded angular; nor discern with
 “ his Eyes, if what his Hands had perceived
 “ to be on high, or below, was in effect
 “ high or low *. He was so long from
 “ knowing Magnitudes, that, after having at
 “ last conceived by the Sight, that his House
 “ was

* This confirms what I was saying above, that it is by
 a Reasoning of Habitude, that the Soul rectifies Objects,
 and judges that an Image, reversed in the Bottom of the Eye,
 comes from an external Object in a right Situation.

The
Sight.

“ was bigger than his Chamber, he could not
“ apprehend how Vision could give this Idea.
“ It was only at the End of two Months Expe-
“ rience he could form a Notion, that Pictures
“ represented solid Bodies. And when, after a
“ long Groping with this new Sense of his, he
“ had perceived that Bodies, and not Surfaces a-
“ lone, were painted in those Pieces, he felt
“ them with his Hands, and was astonished not
“ to find by the Touch those Bodies solid,
“ whose Representation he began to have a Per-
“ ception of; and wanted to know which it was
“ deceived him, the Sense of the Touch, or
“ that of the Sight.”

How OBJECTS are seen DISTINCTLY.

To discern a *single* Object, it is sufficient, as we have seen, to direct the Axes of both Eyes on the Object. To discern it *distinctly*, this first Motion is necessary but insufficient.

Whatcon-
stitutes a
distinct
Image.

An Image is distinct, when all the Points of the luminous Cone that form it meet in the same Proportion as they preserve on the Object itself, without Confusion, or Space, without any Mixture of foreign Rays, and without the Organ's being affected by this regular Collection of Rays either in too lively or in too feeble a manner.

Or, in other Words, an Image is distinct, when all the Points of Light, and the Mixtures of

of Shade that form it, are ranged in successive Order, as they are on the Original itself, so that several of these Points or Mixtures of Shade do not center in a single one, or leave any Spaces between them, that are not in the Original; or, in short, make any Impression, that is not absolutely proportioned to the Sensibility of the Organ. For the one or other of these Defects renders an Image confused.

That all the Points of a luminous Cone conveying an Image may fall near one another in the just Proportion, which renders an Image distinct, the Cloth that is to receive these Rays must be placed exactly in the Degree of Distance E, F, G, Fig. 1. Pl. XIV. from the crossing dd of the luminous Pencils, at which Distance occurs this just Proportion, this exact Order of luminous Points, and of the Points of Shade. Let us form to ourselves a clear Idea of this just Re-union of luminous Pencils, at a certain Point. And, to this End, let us recollect, that each Body scatters around it the Light that strikes it. So that each Pencil of Light, in Contact with a Point of a Body, rebounds on enlarging itself continually; insomuch, that this Point of the Body makes the Top of the Cone, which forms the reflected Pencil. Take in the Arrow A, B, Fig. 1, three of these Points, or of these Pencils, amongst the prodigious Number of those that reflect from the Arrow, and form Cones all around. At whatever Distance you

The
Sight.

The
SIGHT.

place yourself, your Eye will receive a Cone from every one of these Points, and the Basis of these Cones will fall upon your Eye. But to procure a distinct Image at the Bottom of the Eye, that is to say, to cause there a Re-union of each Pencil in one Point, as in the Original that transmits it, and in the same Order, it is sufficient that these Pencils pierce the Eye: because the Refraction in breaking several of the oblique Rays, d, d, and few or none of the others, C, the luminous Pencils must necessarily meet in E, F, G, as they did on the Object A, B. The Points E, F, G, form therefore the optic Plain, the Place where the Image is distinct. It is there then, where we ought to fix the Cloth, the Pasteboard that receives an Image, and in particular the Choroides. If this be more advanced in H, I, K, it will fall in with the Pencil farther enlarged, and the Image will become confused, because these enlarged luminous Points do not render it like the Original; and, being besides dispersed, are mixed with the collateral Pencils, which we must suppose in the Circumference of these to be in infinite Number. If the Choroides, or the Cloth, be at a greater Distance, as in L, M, N, the Point of Re-union will be overshot, and the Cloth will fall in with the Beginning of a new Crossing of Rays, a new Scattering, and a new Divergence of each Pencil, and consequently the Image will be very confused.

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So

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SIGHT.

So that after the Crossing of all the Pencils of Light towards the Crystalline Humour d, d, where all the Rays are confounded in a Heap, as it were, even to the new Crossing of each Pencil in L, M, N, there are only the Points E, F, G, where the Pencils are distinctly reunited, and re-established in the order they preserve on the Original from whence they are reflected.

This Point is not the same in regard of a distant Object, and one near at Hand. The Rays reflected by a neighbouring Object arrive at the Eye more divergent, and more scattered, and their Cone forms a more open Angle. They must therefore re-unite at a greater Distance, and beyond the Focus of the Crystalline, even where the Rays of the Object, were it too near, would not be reunited at all, but would fall parallel to the Bottom of the Eye. It is the Reason why we discern no Object approaching too near the Pupil, or discern it very confusedly.

The Rays proceeding from a distant Object are almost parallel, when they arrive at the Eye. Now such Rays, by the Laws of Refraction, must necessarily re-unite their Pencils at the Focus, or very near the natural Focus of the Eye, and consequently a great deal sooner than those of neighbouring Objects.

Let me add, that Rays reflected by a neighbouring Object are Traces of Light darted from

The
Signs.

from very near, and that the Increase of their Force is in Proportion to the Proximity of the Object, that darts or reflects them. Their Resistance therefore in Regard of Refraction is so much the greater, and the luminous Pencils are re-united of Course at a remoter Distance. On the contrary, the Rays reflected by a distant Object are weakened in the long Track they traverse; their Force is lost, and extinguished by little and little, as is the Case of all communicated Motion. These Rays then give way more easily to the Powers of Refraction, and consequently their Pencils are sooner re-united. The luminous Pencils then of neighbouring Objects are, in Regard of the luminous Pencils of Objects at a Distance, almost what a red Ray is in Respect of a violet-coloured Ray; that is to say, the Pencils of distant Objects are more refrangible. Therefore they must for all these Reasons be re-united sooner, or nearer the Crystalline Humour, than the Pencils reflected from neighbouring Objects. This is no ways here a simple Conjecture, mere physical or geometrical Reasoning, but real Matter of Fact, subjected even to ocular Demonstration.

Be placed in a Chamber over against the Window: hang at this Window a String, a Piece of Wire, &c. Present to these Objects, in the middle of the Chamber, a lenticular Glass, in order to receive their Image, and, at the same Time, that of Objects from without the

the Chamber. Behind the Lens hold a white ^{The} Pafteboard, on which these Images may be ^{SIGHT.} painted.

You will observe, that, when the Objects from without shall be painted clearly on the Pafteboard, the Image of the String hung at the Window will appear on it confused, and like an enlarged Shade. If you would have a distinct Image of this String, you must place the Lens at a Distance from the Pafteboard, and then the Image of the Objects from without the Chamber will be confused in their Turn. If afterwards you have a Mind to see distinctly the Image of these Objects from without, you must advance the Pafteboard to the Lens, or the Lens to the Pafteboard.

The Humours of the Eye perform the Office of a Lens, and the Choroides is the Cloth that receives the Images. Therefore, in order to see distinctly, it is necessary, when we look at a very near Object, that there should be a greater Distance between the Cryftalline and the Choroides; and that, when we look at an Object more remote, the Cryftalline and the Choroides should nearer approach one another, without which the Image is confused.

The Mo-
tions of
the Eye in
order to
see di-
stinctly
both near
and re-
mote Ob-
jects.

It is the Reason why, on looking at a distant Object, the Eye contracts itself, and becomes flatted, its Bottom advancing towards the Entrance of this Organ, in order to meet the Lumi-
nous

The
SIGHT.

nous Cone, that re-unites its Pencils nearer their crossing.

The Flatness of the Humours adds likewise to the Feebleness of this Cone, in producing a less Refraction. For the flatter a Lens is, the less it refracts Light.

These flatter Humours seem to oblige the luminous Pencils to assemble at a greater Distance, or have a longer Focus, like flat objective Glasses. This would be Fact, were the Flatness of these Humours as considerable as that of those Glasses. But as it is moderate, it is not even sufficient to supply intirely the Refrangibility of Rays. It can but partly make way for the luminous Pencils, and the Bottom of the Eye which comes forwards has so much the less to do. It is very obvious how much this Concurrence contributes to render this Mechanism easy. It is an Advantage Glasses are deprived of, that have solid Lens's; and on that Account one is obliged considerably to shorten them on looking at distant Objects.

This small Flatness of the Humours of the Eye causes likewise the total Cone of Light to pass there in a greater Angle, and imprint on the Choroides a larger Image; for the same Reason, as when I put a flatter Lens to the Hole of the dark Chamber, I have the Images of external Objects to a larger Dimension. See P. 231, 232, &c.

When

When, after having looked at a distant Object, and surveyed it in the Magnitude we have been speaking of, one looks afterwards at one that is near, the Eye from being flat, as it was, becomes lengthened, in order to determine the Choroides to the Point of the Union of the Pencils. The Humours are more convex, and refract Light to a greater Degree; and this increased Refraction was necessary to collect the very divergent, very strong, and very little refrangible luminous Pencils of these neighbouring Objects. Notwithstanding this great Refraction, still the Rays darted from too near a Distance, get a little the better of it. There remains to them nevertheless Superiority enough to draw back their Focus, and the lengthened Figure of the Eye comes very apropos to go and receive, and finish, what the Convexity of the Humours had begun; but this Convexity saves it still a Part of the Way.

Humours more convex give smaller Images, as does a more convex Lens in the dark Chamber. So that altho' neighbouring Objects appear larger, by reason they transfix a larger Angle to the Eye, this Angle notwithstanding is less than it would be, in case the Eye could be lengthened without rendering likewise its Humours convex; and Objects would appear larger, if it could lengthen itself, and preserve its Humours flat, in the manner they are, when one surveys a distant Object. Distant Objects

S

appear

The
SIGHT.

appear to us then a little larger, and nearer Objects somewhat smaller than they would seem to us, were the Humours or Lens's of the Eye always under the same Configuration.

It is for this Reason that, when we see a distant Object, while we have our Eyes fixed on a neighbouring Object over against it, the distant one appears to us a great deal smaller and more confused, than when we look at it itself directly. We see it smaller, for Reasons given p. 235. We see it confused or surrounded with Rays, because the Choroides being drawn back, is no longer at the Point where this feeble Cone is subsisting distinctly.

From hence it happens, that there are Persons in the World, that can only see, distinctly, Objects almost under their Eyes; because their Choroides is naturally at too great a Distance from the Crystalline Humour, for the distinct Image of remote Objects to be able to reach this Choroides. Others, on the contrary, cannot see Objects distinctly unless they are very distant; by reason their Choroides is so near the Crystalline Humour, that the Image of neighbouring Objects is not yet formed, when the luminous Cone arrives at the Choroides.

The My-
ope, or
near-
sighted
Eye.

The *Myopes*, or those that can only see Objects very near, have the Choroides too far off from the Crystalline Humour, or from the Crossing of the Rays; either because their transparent Cornea projects too much, the
Crystalline

Crystalline Humour is too convex, and too strong a Refraction makes the Rays cross too soon : or else because, with an ordinary Refraction, their Globe of the Eye is too big, and too much distended, or the Space of the vitreous Humour too large. In both these Cases the optic Point, or the distinct Formation of the Image, is on this Side the Choroides. So that when the Image falls on this Choroides, it is already disconcerted, the Pencils are already divergent, as in L, M, N, Fig. 1. Pl. XIV.

These Sort of People thrust their Eyes almost upon the Objects ; in order to lengthen the Focus by this Proximity, and make the optic Point reach the Choroides. They also successfully make Use of a concave Glass, that lengthens the Crossing of the Rays, and the Point where the Image is distinct. But Age, which diminishes Abundance of the Liquids, and the good Plight of the Eye, as well as of all other Parts, generally corrects this Defect.

Those who discern nothing but at a great Distance, have the Choroides, H, I, K, too near the Crossing, d, d, of the Rays ; either because they have the transparent Cornea or the Crystalline Humour too little convex, or else the vitreous Space too small.

If they have the Cornea, or the Crystalline Humour too little convex, the Refraction is feeble, the Crossing is made at too great a Distance, as is the Re-union of the optic Pencils.

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So that the inverted Cone gains the Choroides in H, I, K, before the Pencils are united, and before the Image is distinctly formed, as it is in E, F, G.

Tho' the Refraction and Crossing are as usual, yet if the Apartment of the vitreous Humour be too small, too short, or flatted, the Choroides will be still on this Side the optic Point, and will receive no distinct Image, unless that of very distant Objects, that have a shorter Focus, and require precisely a Choroides near the Crystalline Humour, as these Presbite Eyes have; a common Defect in old People from a general Aridity of the Parts. This Defect is corrected with convex Glasses, Microscopes, and a Lens which augments the Refraction, and renders the Crossing of the Rays and their Focus shorter. But this is the sole Resource remaining to those who labour under this Inconvenience. For the Presbite Eye has not, like the Myope, the Advantage of being amended by Age. Time, on the contrary, serves only to render its Condition worse.

A well formed Eye is therefore that, wherein the Image of Objects, at a middle Distance, falls distinctly on the Choroides without any Violence offered to this Eye; which supposes a regular Figure of the Parts of the Eye. But a good Eye is that, which adds to this regular Conformation, the Talent of seeing distinctly at all Distances; because it has the Power of metamor-

metamorphosing itself into a Myope, or dilated Eye, when it surveys very near Objects; or into a Presbite, or flatted Eye, when it looks at Objects that are very remote.

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This Power the Eye is endued with of dilating or contracting itself, can only reside in the Muscles, and ciliary Fibres, that surround and move the Crystalline Humour.

How the
Eye is ex-
panded to
view near
Objects,
and flatted
for those at
a distance,

When we look at a remote Object, we twinkle the Eye-lids, that seem to press upon the fore Part of the Globe, in order to flat it. The Eye seems also to sink to the very Bottom of the Orbit, by the Contraction of all the streight Muscles, which line this Bottom with their inflated Bellies; and, drawing by their Tendons the anterior Hemisphere against it, must flat of course both the one and the other by its Poles; and make the Choroides by that means approach the Crystalline Humour, and perhaps render that Humour itself flat.

When, after having viewed a remote Object, we look immediately at an Object that is very near us, situated on the same Line as the former, we are sensible of a Rotation, and a violent Agitation inwardly, tho' no outward Motion be perceived in the Globe of the Eye. The Eye-lids are dilated, and the Eye seems to advance out of the Orbit. Being pressed laterally, or according to its Equator by its Muscles, it becomes flat, pursuant to this Dimension, and is dilated by its Poles. The Corona Ciliaris is

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is at the same time contracted, and determines likewise the Portion of the Globe that is fastened to it towards the Axis, and the CrySTALLINE Humour towards the Pupil. By that means it so much contributes to the Dilatation of the Eye, and to the causing a greater Distance between its Bottom and the CrySTALLINE Humour. It is even possible, that by pursing up this thro' its whole Circumference, in concert with the lateral Pressure of the intire Globe by the Muscles, it helps likewise to render this Lens more convex. The CrySTALLINE Humour is not of sufficient Solidity to be unsusceptible of these Alterations; and the small Quantity of Humours besides, which lubricate the Inside of its proper Coat, give Liberty enough to this Coat to change also the Figure of its Surface. Cannot one add to these Proofs the Observations in p. 232, &c? In short, it is very requisite, that the CrySTALLINE Humour, and its ciliary Fibres, should be capable of all these Motions in Animals, which have the first Coats of the Eye absolutely solid and inflexible. Such are, for Instance, the Eyes of the Whale, which some anatomical Travellers, that have dissected them, have assured me are as hard, externally, as so many Balls of Ivory. They affirm likewise, that Whales see very well at all Distances; that without such good Eyes, they could not either give Chace to other Fish, or avoid those that are on the watch

to

to catch them, with so great a Sagacity as they do ; and that the Opinions of some Authors, of their having a Fish to conduct and guide them, are merely fabulous. However, were Whales actually short-sighted, the Reason of it would be intirely discovered, and would be a further Proof of the Necessity of the Motions just attributed to the Eyes. But in case a Whale sees at different Distances, its solid Eyes being incapable either of dilating or contracting themselves, it is very necessary that the CrySTALLINE Humour supply that Defect, by projecting, or subsiding, and so becoming more or less convex, thro' the Action of the Ciliary Fibres.

The interior Violence accompanying the Action of these Fibres, is what most strains an Eye obliged to look at a near Object ; and is generally that which so much fatigues the Eyes of those that look with Application, and for a great while together, as they do who read a good deal : because this Application supposes a continued Tension of the Ciliary Fibres in order to put and retain the Eye and the CrySTALLINE Humour, in Situations proper for distinct Vision.

The Pupil, when it is a perfect one, gives us a Specimen of this Contraction of the Corona Ciliaris, by a small sympathetical Contraction, which it owes to their common Origin.

I said that one twinkles the Eye to look at Effect of a remote Object, by compressing the anterior the cling- Hemisphere of the Globe, and that one dilates Eye-lids.

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the Eye-lids to see an Object near, not inasmuch as these two States of the Eye-lids are absolutely necessary to give to the Globe the Figures it ought to take in the Cases proposed. These Figures of the Globe have other Causes of greater Power and Force, and one may, without disconcerting their Effects, twinkle the Eye-lids both in one and the other Case. We actually do so every time we make Efforts to see better, either in regard of distant or near Objects. But this kind of twinkling bears no Analogy with the Figure of the Globe. All its Mechanism terminates in straitening the Eye-lids, in order to hinder the Rays from falling in too great a Quantity on the smooth Surface of the Cornea; from whence they are reflected and scattered around to the Prejudice of the Clearness of the Rays which enter the Eye. It is the Reason, why we mechanically twinkle our Eyes, to permit a Passage to almost nothing but the Cone of Light that conveys the Image, and to prevent this Image from being disturbed, and soiled, if one may be allowed the Expression, by foreign Rays. Hence likewise we see an Object better thro' a Tube, than in open Air.

**Effect of
the Con-
traction
and Dila-
tation of
the Iris.**

It is by a like Artifice, that the Iris, which is a Part derived from the Choroides, contracts itself on being struck by a very strong Light. On which Account, it lets pass a less Quantity of Rays, which affecting this Organ more moderately produce in it a distincter Impression.

On

On the contrary, the Iris is dilated, when the Light is feeble; because the Choroides, not being sufficiently stimulated by this feeble Light, leaves the Iris in a State of Relaxation: and this very Relaxation makes the Iris, thus enlarged, receive a greater Supply of Rays. So that the Quantity of these Rays repairs in some measure their Feebleness, and produces an Image as distinct as possible.

Altho' the Eye-lids, like the Iris, concur to preserve the luminous Cone, that enters the Eye, more pure, and to render the Images more perfect; if, notwithstanding, we look at a Candle with our Eye-lids drawn so near together, that they partly close the Pupil, and intercept a Portion of the luminous Cone that ought to enter it, we no longer in that Case see the Candle clearly, but with great luminous Traces directed towards the upper and lower Part of this Light; which large Traces are the Portions of the Cone reflected by each Eye-lid. But the Eye-lids do not thus disturb the Sight, but when they are closed in the manner I have been hinting; nor has the Object these large Traces of Light, but above and below. These are Circumstances, that never entered into the Thoughts of a Naturalist*, worthy of all Esteem for his Piety, when he ascribed the Rays of the Stars to this Reflection, produced by the Eye-lids being fond of erecting this Defect to a Per-

* The Author of the Spectacle of Nature.

The **SIGHT** Perfection destined by the supreme Being to embellish the Spectacle of the Universe.

Why the Planets are encircled with Rays. We must therefore seek elsewhere the Cause of the Rays that surround the Planets.

These Rays are of several Sorts. First, we find around the Sun, a kind of luminous Atmosphere, which almost to the Life resembles that easily observable round this Planet, and about the Moon herself, in some particular Fogs.

Secondly, we observe likewise in the Planets, and principally in the Stars, a certain trembling Motion, that subjects their Image to a perpetual Alteration of Figure; and luminous Traces and Angles seem at the same time to dart from their Circumference.

Thirdly, in short, the Sun in particular, when seen in a very clear Sky, appears surrounded with a sparkling Atmosphere, insupportable to the Eyes.

The luminous Atmosphere that encircles the Sun, is not altogether an Illusion of the Sight. It is natural enough for this intirely fiery Planet, to have at least an Atmosphere of very clear and very lively Light, and it is this Atmosphere, that is so intolerable to our Eyes*. The Mediums, the Image of the Sun passes thro' to come to us, are, perhaps, a farther Augmentation of the Appearance of this Atmosphere; because

* The celebrated *Monf. de Mairan* established this Atmosphere in his Treatise on the Light of the Zodiac.

because when these Mediums become grosser, they make the Images of all the Planets appear surrounded with a Crown of Light. If we put a fine Linen Cloth between our Eye, and the Light of a Wax-Candle, we shall see this Candle surrounded likewise with a Circle of Light; by reason the Threads of the Cloth, which the Light of the Candle passes thro', disperse and scatter a Part of them out of the regular Cone naturally formed by this Light; and from the Portion of Light thus turned, and scattered round this regular Cone, results that remarkable Circle. Ethereal Matter, and the Earth's Atmosphere act, in regard of the Images of the Planets, what the fine Cloth does in respect of this Light.

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Without putting the Cloth before a Candle, if one looks at it from the Distance of a hundred Yards, we shall see it surrounded with Rays, and Traces of Light; because the luminous Filament, which conveys this small Image, is not able to preserve its regular Figure, thro' so long a Space of Air. Hence several Pencils in the Circumference of this small Cone are turned, and rendered more divergent than the rest; and so by these small Scatterings form those Traces and Rays, that surround the Body of this Light, or principal Cone. Now, tho' the Distance of a hundred Yards be necessary for seeing a Candle encircled with Rays, that of two Feet is sufficient for seeing a Spark of Fire in the
same

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same State; because the luminous Filament of this Spark is extremely fine and feeble. The Stars, by reason of their Distance, are feeble Lights seen from a-far, mere Sparks, as it were, whose luminous Filaments are not able to preserve their Regularity as far as us. The Moon is not encompassed with Rays like the lesser Planets, because her luminous Cone, being of vaster Extension, makes the better Resistance, in regard of the Mediums it passes thro', so that her Image arrives in a regular manner at the Bottom of the Eye. The small Planets, seen thro' large Telescopes, are equally without Rays, because the Glasses of these Telescopes collect the Rays scattered in the Circumference of the Image, re-establish it, and render it regular.

As to the trembling Motion of the Planets, that proceeds likewise from the Mediums their Images pass thro'; not from those grosser Mediums like the Atmosphere, but from the subtile ones, such as ethereal Matter, and the Matter of Light. These Mediums which fill and compose the celestial Spheres, are incessantly in Motion, and the Motion peculiar to Light, or to its Action and Function, as Light is the Motion of Vibration. The Images of the Sun and Stars, that come to us thro' all the Spheres, must partake of all these Motions, and consequently undergo a proportional Alteration, in regard of their Regularity. Now this Alteration is precisely the trembling Motion that affects the

the Brilliancy of the Planets, of the Stars particularly, whose Image have several Spheres to pass thro'. One has a gross kind of Resemblance, tho' constant enough, of this trembling Motion, when we look at a Star, or the Sun, reflected from the Surface of Water a little agitated.

When the Choroides is affected by too lively an Impression, one sees Sparks with it: and even a Stroke received on the Eye makes one see Sparks, because these nervous Parts are very strongly affected. The direct Impression of the Sun on our Eyes, is certainly one of those that affect this Organ too violently. Its Image of course must be accompanied and surrounded by Sparks. And this, in respect of the luminous Atmosphere, is all that is therein remarkable. For I cannot tell from whence the regular Traces could have been taken, with which it has been encircled with Rays, unless from the Imagination of Painters.

To deprive the Sun of all his Rays, we have nothing more to do, than to look at this Planet thro' a Pin-hole, either on his setting, or in a Pail of Water. Because the Impression made on the Choroides in all these Cases is very feeble, and consequently void of Sparks. He is then reduced almost to the Condition of the Moon, whose soft Light is imprinted clearly, and without the least Embarrassment on the Choroides.

Let

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Let us end this Essay on Vision with the Explication of some optical Phenomena, Part of which are omitted in the Articles where they should have been ranged, and the rest having a Connexion with several Articles occur here in their natural Place.

Sequel of the Phenomena of VISION.

I.

How the
Images of
Objects
are seen re-
versed,
which en-
ter in the
dark
Chamber,
and why
these same
exterior
Objects
are seen
in a right
Situation,
when sur-
veyed
thro' the
Hole of
this
Chamber.

WE have seen thro' all the preceding Dis-
course, that Images cross one another,
and are reversed in the Eye, as they are in the
dark Chamber. If, notwithstanding, we are in
a dark Chamber, and look thro' the Hole at ex-
terior Objects, we shall see them strait. These
Objects, nevertheless, fall reversed on the trans-
parent Cornea, as they do on the Pasteboard,
subservient to the Experiment of this Chamber.
In case the Eye makes them cross again, they
are of course in a right Position. Now Objects
painted right in the Eye must be seen reversed.
So that those exterior Objects must consequently
be seen reversed, which one looks at thro' the
Hole of the dark Chamber.

We see the Images reversed, painted on the
Pasteboard, d, d, of the dark Chamber, Fig.
2. Pl. XIII. because these Images reversed and re-
flected by the Pasteboard towards our Eyes, e,
cross once more in these Organs, and go to be
painted in a right Situation on the Choroides :
and

and these reflected Images cross again in the Eye, by reason their Rays are parallel, or convergent. Exterior Objects, seen immediately thro' the Hole of the dark Chamber, would equally be seen reversed, did their Images likewise cross in the Eye. But this is not the Case. They fall in the Bottom of the Eye reversed, Fig. 3. as they are on the Cornea, and on the Pastedboard; because these immediate Rays, far from being parallel, or convergent, like the Rays reflected by the Pastedboard, d, d, are extremely divergent: insomuch, that it is impossible for the Humours of the Eye to make them cross again. These Humours only collect them, as the convex Glass does, placed at the Hole of the dark Chamber, and nothing more. See Fig. 2, 3, Pl. XIII; where these Truths are expressed. A, Fig. 2, is a Steeple seen thro' the Hole c, of a dark Chamber; d, d is its Image painted reversed on the Pastedboard. The Reason why it is seen reversed, is because the Rays reflected towards one's Eye, e, cross afresh, and thereby rectify the Steeple. In Fig. 3, the Eye D looks at the Steeple A immediately thro' the Hole C of this Chamber. The Rays C D being too divergent, cannot cross in the Eye D. Hence they paint the Steeple reversed, as if one looked at it out of the dark Chamber, and on that account, we see it in a right Situation.

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All the World knows, that, in order to rectify Objects in the dark Chamber, we must place at the Hole of this Chamber two lenticular Glasses; to wit, the first at the Hole itself, C, Fig. 5. the second E separated from the former a little more than two Foci of these Glasses. The first Glass C brings back the divergent Rays, C, towards the Parallel. The second Glass E recovers these parallel, or almost parallel, Rays, makes them cross afresh, and thus rectifies the Image in F. This Image appears right to the Eye D, because being reflected by this Eye, it there crosses and is reversed, as if the Image came directly from the Object A. Consequently, neither the first Glass, nor the Eye, is capable of making the Rays cross, and so rectify the Images at the Bottom of the Eye, as we see it does, Fig. 3. These Images then will be there reversed, and the Object seen thro' the Hole of the dark Chamber would appear right.

II.

How a
Pin in a
right Situ-
ation may
appear re-
versed.

The Hole of the dark Chamber, that exhibits Objects reversed on the Pasteboard, d, d, lets them notwithstanding be seen witho ut in a right Situation. But here follows another Experiment, where, on the contrary, a right Object disposed before, and within this Hole, appears reversed and placed on the Outside of this Chamber.

With-

Without recurring to a dark Chamber, put before your Eye D, (Fig. 4, Pl. XIII.) a black PASTEBOARD, B, pierced with a Pin-hole, C. Place over against and beyond this Hole, a very illumined Body, such as a Sheet of white Paper, E, enlightened by a Flambeau, G. Hold afterwards a Pin, d, before your Eye, D, and you will see with Surprize the Pin reversed, and on the other Side of the Hole in F. Which Phœnomenon is thus accounted for.

The Images of exterior Objects, it is well known, in passing thro' the Hole, C, Fig. 2, 3, are reversed, and painted thus reversed, either on the PASTEBOARD, d, d, or in the Eye, D. The same Thing happens in regard of the Images which pass thro' the simple Pin-hole, c, Fig. 4. and goes to be painted in the Eye, D. At the Place where the Pin in a right Situation, d, is put, the Images are already reversed. Now this Pin occurring with these reversed Images, stops the Rays that correspond with it, and, consequently produces in these Images a Deficiency of Rays, or the Shadow of the Figure of a Pin. This Pin in the midst of this reversed Image is right. The Image of the Paper, E, will therefore go to be painted at the Bottom of the Eye in a reversed manner, having in the middle of it a Shadow of a Pin in a right Situation. Now the Soul judges Objects right, that are reversed in the Eye, and reverses those that are there right. Whence she will see

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the

The the exterior Objects, E, in a right Situation,
SIGHT. and the Shadow of the Pin reversed. She will
 moreover see this Pin, or rather its Shadow,
 beyond the Hole in F; because the Pin she sees
 is only in Effect a Shadow produced in the
 Image of the exterior Objects, E. This ima-
 ginary Pin ought therefore to be the exterior
 Objects, E, and seen beyond the Hole.

III.

Why the The Eye is not only deceived in regard of
quick the Situation of Objects, by seeing those rever-
twirling sed that are right, and those right that are
about of a sed reversed; but is still more frequently deluded,
burning and with less Art, as well in respect of the Situ-
Coal seems ation, as of the Figure of Objects, when a lighted
a Circle of Charcoal whirled around shall seem a Circle of
Fire. Fire; or when a very small Fiddle-string shall
 be made to appear large, or seem to be several
 on the Side of one another, by solely exciting
 Vibrations in this fine and single String.

These Phœnomena depend on the Duration of
 the Sensations, which an Object excites in the
 Nerves, and on the Quickness with which the
 Action of it is repeated. When a Spark of Fire
 burns us, the Smart continues for a while,
 after the Spark is extinguished; and the Im-
 pression of Savours and Odours remains likewise
 a certain Time, after the Objects have ceased to
 affect the respective Organs. In like manner,

altho'

The
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altho' Light be of a much more subtile Nature, its Impression nevertheless subsists a limited while after its Action. Now if the Action of an Object is renewed on a nervous Papilla, before its former Impression is extinguished, the Impressions will be continued, as if the Object had not ceased to act. This is the Case in regard of the fiery Circles produced by the frequent and rapid Whirling of a burning Coal thro' the same Track. Its Actions on the same nervous Papillæ of the Choroides succeed one another, with such Rapidity, that the Impressions they there excite are continued; so that having in the Eye an uninterrupted Circle of the Impression of Fire, we necessarily see a fiery Circle. This is the Reason likewise, why Drumsticks by a rapid Succession of one another on beating this Instrument, produce the continued Noise called the *Ruff*. The String of a Violin enlarged or multiplied by Vibrations are explained by the same Principle.

A Light, that rapidly traverses a Space in the Heavens, seems there still a continued one. Because the Line of lively Impression it describes in the Eye, is made with that Celerity, that all the Points of this Line of Impression subsist at once a certain Time. Consequently, one has in the Eye an intire Line of luminous Impression, and therefore one must see a continued Light. Such are those Meteors, stiled by the Vulgar, *Falling Stars*.

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IV.

Observations on the Sight of a distant Object, and that of a Wire placed very near the Eye on the same Line.

I looked at a distant Steeple with one Eye, and put before it a Wire not so thick as my Pupil is large. I saw the Steeple notwithstanding the Wire, and as it were thro' the Wire, which appeared to me like a thick Shade corresponding with the Steeple. I saw nevertheless this Steeple intirely. I afterwards looked at the Wire itself, and saw it distinctly without Shade, and smaller than the Shadow I saw of it on looking at the Steeple. But it was not all transparent, and, tho' absolutely very small, hid from me a Part of the Steeple. This Steeple in its turn, which I saw without looking at it on the Side of the Wire, appeared to me a great deal smaller than when I looked at it directly.

When I looked at the Steeple directly, I had my Eye contracted, and flatted by the Poles, in order to receive the luminous Cone, at the optic Point, and I saw it distinctly, and in its natural Magnitude. In this State, the Choroides too much projected for the luminous Cone of the Wire, and the Pencils of the same luminous Points reached this Choroides befor their Re-union, and reached it besides separated from one another, and leaving void Spaces between them. Hence, when I passed the Wire before my Eye, it seemed to me like an enlarged and transparent Shadow.

I saw the Steeple thro' this Shadow, because the Separation of the luminous Pencils of the Wire, left Spaces large enough for the distinct Reunion of the optic Pencils of the Steeple.

When I looked at the Wire itself, I saw it distinctly and smaller, because I then dilated my Eye, and determined my Choroides to the Point, where the luminous Pencils of this near Object went to reunite themselves distinctly, and by reason in this Point the Pencils are reduced to a smaller Space. The Wire at that Time, tho' not so large, hid from me Part of the Steeple, because the luminous Pencils of the Wire, being very compact, left no more Space for those of the Steeple corresponding with them, and thus totally effaced them. This Steeple, seen on the Side of the Wire, and without looking at it directly, seemed smaller than when I did look at it, because when its Image fell on my Eye, it became more convex, in order to see the Wire; and this Figure of my Eye produced a large Refraction in the Image, which was rendered so much the smaller in it.

V.

To these Observations, that regard the Distinction and Magnitude of Images, I will add some others of a very singular Nature, occasioned by the former.

New Op-
tical Phae-
nomena.

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Objects
magnified
by the In-
terposition
of a Wire,
or a Pin-
hole.

As I was looking at the same Steeple, and frequently passing a Wire backwards and forwards, before my Eye, I casually perceived with Surprise, that every time the Wire passed before my Pupil, the Steeple seemed to move and leap, as if I had passed before my Eye the Glass of a Telescope. The Mountains that were behind the Steeple had intirely the same Motion.

On a closer Examination of the Matter, I observed that the only Case, where the Steeple did not leap, was when I made use of a certain very narrow Medium, and a very difficult one to keep. There the Image of the Steeple was not so distinct, and seemed to me enlarged.

I was struck with these Circumstances, that obliged me to observe in the Wire a kind of Lenticular Glass. For I surmised even at first, that the Steeple seemed to move, inasmuch as the Wire, being placed in the middle of its Ray, enlarged the Image of this Steeple, and because, on the Wire's being past that middle, and the enlarged Image's suddenly returning its ordinary narrow Bounds, the Steeple looks as if it were in real Motion; as an Object, before which one passes a Lenticular Glass, appears refracted and moved.

In order to be assured of the Reality of this Conjecture, I accommodated my Eye to the Steeple in such a Manner, that its Image came to my Eye glancing very near the Side of the Window,

Window, where I observed it. I again passed my Wire, and saw that, when it was in the visual Axis of the Steeple, the latter seemed nearer the Window, on whatever Side the Wire came; because the Image of the Steeple enlarged by the Wire diminished in that Proportion the Space I had made between these two very near Objects. I observed likewise, that when this Image was contracted, by withdrawing the Wire, it was so much the more remote from the Window. Hence, on executing with Celerity what I had been doing deliberately, the Steeple seemed to leap on its approaching to, and retiring from the Window.

After this Confirmation of my former Conjecture, I repeated the Experiment in a very clear Season, which still equally succeeded. And the Wire, being held fixed and exactly in the middle of the Steeple, never fails to make it appear a great deal larger, and as it were double. The physical Cause of this singular Phenomenon is as follows.

This Medium, where the Image of the Steeple is confused, larger, and as it were double, is when the Wire is exactly in the Axis of the Image of the Steeple. In this Situation, the Wire divides the luminous Cone, that conveys this Image into two equal Parts, and intercepts the perpendicular Filament of it, which is what contributes to render the Image incomplete and confused.

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The Confusion of the Image of the Steeple is all one can attend to, from the Interposition of such a Body as a Wire: it is notwithstanding much less perceptible than its Enlargement.

The Confusion is slight: Therefore the Wire intercepts but few Rays. It is nevertheless of such a Thickness, that it ought to hide from me at least the whole Steeple; for I see an intire Plain, of which the Steeple does not make a hundred thousandth Part. The Wire is almost a Line thick, my Pupil thro' which the Image of all this Plain passes, contains but a Line and a half, or two Lines at most, and the Wire is only the Length of an Inch of it. Conceive then a Cone of Light, with a Base more than a hundred thousand Times as large as the Steeple, and place within an Inch of its Top an opaque Line, and you will see what an Angle this Line will describe on the Base of the Cone, and how many Steeples it will cover.

It therefore necessarily follows, that the greatest Part of the Rays, which occur to the Wire, are not stopped by it and extinguished; for a great many of them are requisite in order to one's seeing the Steeple. On the contrary, these Rays must circulate a little round the Wire, or turn from their right Line to accommodate themselves to its Circumference, somewhat like what a Filament of Water or Air would do. By means of this turning, our Eye will have

have almost the whole Image of the Steeple, which of course will be very little confused.

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That is not all. This Image of the Steeple appears enlarged. Now an Instrument that enlarges an Image, only does so by rendering its Rays convergent, or at least by making them cross in a wider Angle. Thus, as the Wire enlarges the Image of the Steeple, it necessarily follows, that as one half of its Circumference which fronts the Object, turns and renders the Rays of the Steeple divergent, so the other that fronts the Eye, turns these same Rays convergently towards this Organ. There is therefore thro' the whole Circumference of the Wire, a certain Power, that collects towards the Eye these same Rays which it had at first scattered. To that End this Power must of course apply these Rays to the Circumference of the Wire, and oblige them to follow this Circumference even to a particular Point. In a Word, the Circumference of the Wire must in regard of these Rays be endued with an Attraction intirely like that observable in Glafs. Now we have seen that this Attraction is nothing else than an Impulse of the Fluid which surrounds the Wire; and that these Rays are thus applied to the Wire, as a Filament of Water is to a Stick, or a Piece of Liff presented to it.

This surrounding Impulse therefore determines these Moieties of the Image to turn round the Wire, and by that means makes the whole

The whole Image appear double. **This Impulse**
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 as possibly it can, against the Circumference of
 the Wire, which Effort produces a Turning of
 these Rays towards the visual Axis. Conse-
 quently they cross with greater Celerity, and in
 a larger Angle, and of course form a larger
 Image.

Thus then are Rays refracted in Convergence,
 and an Object enlarged by a Wire, in the same
 manner as it is by a Lenticular Glass, what has
 never, I imagine, been before furnished.

Not only the narrower luminous Cone, pass-
 ing in the Eye, without the Wire, occurs thus
 collected in Convergence; but the Wire like-
 wise becoming thicker than this first Cone, its
 Surface must necessarily attract the collateral
 Rays, or Portions of a larger Cone, and collect
 this larger Cone in Convergence in the Bottom
 of the Eye, which of course must produce a
 larger Image.

In order to convey a clearer Idea of this
 Phenomenon, and its Explication, I must desire
 the Reader to consult Fig. 2, Pl. XIV. The
 black Lines describe the narrow luminous Cone
 that conveys the natural Image of the Steeple A,
 to the Eye B, when the Wire is not before the
 Pupil, where it is evident, the natural Cone is
 much narrower than the Wire C. The pointed
 Lines not only mark the first luminous Cone
 stopped

stopped and turned by the Wire C; but they describe likewise the collateral Rays more scattered, which are attracted by the Wire, and collected in Convergence in the Pupil, in the same manner as we have seen in the Plate of Pl. XII. Fig. 2, the Lenticular Glass assembles in the Pupil the collateral Rays g, h, which would not have been entred there without this Refraction; and by that means the pointed Cone, thus collected in the Bottom of the Eye B, makes there a larger Angle, and a larger Image, than the Cone marked by the black Lines, which is the natural one. As to what remains, the Experiment equally succeeds with every other Body as with the Wire, provided it be as narrow.

This Discovery, which depends on the Inflexion of Rays, towards the Surface of Bodies, has conducted me to several others depending on the same Principle. For Instance, I have also enlarged small Objects, such as a Pin's Head, by looking at them thro' a very little Hole, made in a Pasteboard, in such a manner, that the Image might sufficiently approach to the Circumference of the Hole to be stopped by Objects it and enlarged. I have moreover remarked, enlarged and attracted by on looking at some singular Objects, such as a live Coal amidst Cinders, or a Piece of fresh Charcoal, just thrown into the Fire, &c. that the Proximity of the Surface of Bodies, if one draws one's Finger, very near the optic Cone

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Cone that conveys its Image to the Eye, this Object appears to dilate itself towards the Finger, and, as it were, to precede it; and that when the Finger withdraws from it, it seems still to lengthen itself, in order to follow it to a certain Point. It is for the same Reason, that the Clouds which pass before the Sun, impart different Motions to the Shadows of Bodies, and that when these Clouds are interrupted here and there, those Shadows seem as it were to dance. This Effect is principally perceptible in the Shadows formed by the Lead of Glass-windows. It is also to this kind of Refraction of Rays, by the Fluid which surrounds Bodies, that I partly ascribe the Colours of a Rainbow, produced by a very thin Pin placed near my Eye, and on which I have caused to fall obliquely the Light of a Wax-Candle.

Colours of a Rainbow produced by a Pin.

It is now Time to conclude this Essay on the Senses; and, perhaps it may be objected I ought to have done so sooner, having by a great deal surpassed the Bounds I prescribed to myself. But how can one resist the Torrent of curious Matters, that present themselves under these Articles! And yet how many have I let pass with Regret, circumscribed by these same too narrow Limits? The Nature and Mechanism of the Senses constitute a Matter the most interesting of all Physics. These are our means of Correspondence with the rest of the Universe.

It

It is the Reason, why this Part of Physiology is so linked with all the Parts of natural Philosophy, that it is almost impossible to treat of the Senses, without touching at the same Time, slightly at least, on the other Branches of Physicks.

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I have above remarked, that this Commerce between the Universe and us, is ever carried on by a Matter which affects some Organ; and that from the Touch to the Sight this Matter is more subtile, more and more diffused at a Distance from us, and on that account more and more capable of extending the Bounds of our Commerce. Bodies, Liquids, Vapours, Air, Light. This is the Gradation of these Correspondences, and the Senses by which they are carried on are our Interpreters, and our Intelligencers. It is observable, that the greater the Distance is from whence our News arrives, the more subject it is to Uncertainty; which is verified in most of our Relations of long Voyages. The Touch, the most limited of the Senses, is at the same time the surest of them all. The Taste and the Smell have likewise a sufficient Certainty: but the Hearing is in many Instances too apt to deceive us. As to the Sight, Vision is subjected to such a Number of Errors, that the Industry of some particular Persons, skilled in drawing Advantages from every Circumstance, have invented Projects and formed them into an Art, on purpose to impose on the Eyes: an Art.

The Senses are the Means of our corresponding with the Universe.

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Art so admirable, and carried so far by Painters, and even by those of the most remote Antiquity, that we are thereby deprived of a Possibility of having Senses that could less deceive us.

Every
Thing is
conjectu-
ral, un-
less we
take the
Senses for
our
Guides.

Our Senses are subjected to a thousand Mistakes; and yet we know nothing, but what they apprise us of, or what they give us Grounds to conjecture, by comparing those Hints with what they demonstrate to us. For Instance, Light, the particular Fluid that renders Bodies visible, puts us on imagining there is another Fluid that gives them Gravity, another that makes them electrical, or determines the Needle to turn to the North, &c. And we endeavour to guess at the Figure and Motion of these imaginary Matters. Let us attend to the Train of Conjectures, and we can be under no manner of Doubt, but that all our Knowledge is at best derived from what the Senses point out to us.

Our Igno-
rance pro-
ceeds from
the small
Number
and Un-
certainty
of the Sen-
ses.

Judge from hence of the strait Bounds, and of the little Certainty there is in our Acquaintance with Things, which consists in seeing a Part of them, by the Help of deceitful Organs, and in divining the rest. How comes Nature, you will say, to be so good and so liberal? Has she not furnished us with Senses for all these Phenomena, which we are constrained to guess at;

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for Instance, for this Fluid of Gravity; for that which moves the Needle; for what gives Life to Plants, to Animals, &c? A Method more concise of rendering us intelligent, in respect of these natural Effects, which otherwise become Mysteries. For, in short, the five Species of Sensation, which are Embassadors, as it were in our Regard, from the States of the material World, can only supply us with a slight Idea of them. Let us imagine to ourselves a Sovereign of the Universe, who had no other Notion of all the People spread over the Face of the Earth, than what he had received from a *Frenchman*, a *Persian*, an *Egyptian*, and a *Creolian*, and all four deaf and dumb. For of this Kind are more or less all the Species of Matter. It is true, modern Philosophy has discovered Prodigies of Invention to interrogate these Embassadors. But suppose they will one Day reveal themselves to us, there is still no Appearance that they will ever unfold what all the other Nations of Matter are, that are foreign to them.

It is a Point worthy our Consideration, that Senses more multiplied than ours, might possibly have embarrassed us, or that the greedy Curiosity they had inspired us with, might have been the Source of more Inquietude than Pleasure. Is not the good Use of those we have, sufficient

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to our Happiness? Let us then congratulate ourselves, as Philosophers, in the Privation of these imaginary Riches, by employing those well which we are blessed with the Enjoyment of. This is our Destination, the Will of the supreme Being, and the End of all sound Philosophy.

F I N I S.



